To my dearest M.

from J.

Christmas 1926.

To my dearest M.

from T.

Christmas 1920.

PLATE I. Crion and the Bull (*see p. 170*)

(*Orion et le Taureau*)

(From *Atlas Céleste de Flamsteed*, Second Edition, A.D. 1776)

The Call of the Stars

A Popular Introduction to a Knowledge of the Starry Skies with their Romance and Legend

By

John R. Kippax, M.D., LL.B.

Author of "Comets and Meteors," "Churchyard Literature," etc.

"O ye Stars of Heaven, bless ye the Lord:
Praise him and magnify him forever."

BENEDICITE.

Fifty-five Illustrations

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To

C. C. K.

PREFACE

The design of this volume is to present, in plain, non-technical language, a concise and accurate story of the starry heavens, together with the legendary lore that time and fancy have associated with them. In its preparation the author has consulted and freely used the standard authorities along the various lines of astronomical research, and to these his grateful acknowledgments are due.

The book is not intended for the professional reader, who is doubtless already familiar with the facts here given, but rather for the lay reader, who has but limited time to devote to the subject, and yet who desires to know about the wonderful things in the sky, with their interesting myths and legends.

The work is richly illustrated by charts and diagrams, and by a large number of reproductions of recent photographs made by distinguished astronomers.

The charts as arranged are approximately correct for every place on the surface of the earth situated within a few degrees north or south of the latitudes of New York and Chicago (40° 43′ and 41° 53′ north latitude, respectively), and for all ordinary purposes represent the aspect of the sky for the different places in any of the middle latitudes of the northern hemisphere, at the *local* time of each place, whatever the longitude may be. With their assistance it is believed that the

reader will experience but little difficulty in recognising the general contour of the chief constellations, and the relative position of the principal stars, and will find uplifting pleasure in viewing the "oldest picture-book of all," *The Night-Sky*, "a book whose pages turn with the gliding years."

The sun, planets, and other members of the local solar system are described in the later chapters of the book. Owing to their ever-changing positions, however, it would be quite impossible to locate them on the charts, after the manner of the fixed stars.

The author desires to express his indebtedness to the following individual astronomers for the use in the book of the reproductions of the many excellent photographs and drawings: Professors William H. Pickering and E. C. Pickering[1] of Harvard College Observatory; Professors A. Hall, G. A. Hill, and G. H. Peters of the Naval Observatory, Washington; Professors E. E. Barnard and E. B. Frost of Yerkes Observatory; Professor Percival Lowell[2] of Lowell Observatory; Professor P. Puisseux of Paris Observatory, France; and the Directors of the Lick Observatory and the Mount Wilson Observatory of the Carnegie Institution, California.

To other friends for kind and gracious service his best thanks are also due: to Mr. C. J. Helm for drawings from the author's rough drafts, and to H. Kippax, C. E., for the interesting article on Time.

In conclusion, it is hoped that the book may be of service in helping on a rapidly growing popular interest in the heavenly bodies and their stories.

J. R. K.

January, 1914.

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[1] Dr. E. C. Pickering died February 3, 1919.

[2] Dr. Percival Lowell died November 12, 1916.

CONTENTS

PART I

THE STARS

ILLUSTRATIONS

PLATES

PAGE

DIAGRAMS

CHARTS

SOME AUTHORITIES CONSULTED

The Sun	C. G. ABBOT
Star-Names and Their Meanings	R. H. ALLEN
Through the Telescope	JAMES BAIKIE
Popular Guide to the Heavens	SIR ROBERT S. BALL
The Birth of Worlds and Systems	A. W. BICKERTON
Astronomy for All	B. H. BRUGEL
Geography of the Heavens and Celestial Atlas	E. H. BURRITT
Astronomy	G. F. CHAMBERS
The System of the Stars	AGNES M. CLERKE
Astronomy of To-day	C. G. DOLMAGE
The Night-Skies of a Year	J. H. ELGIE
The Stellar Heavens	J. E. GORE
The Growth of a Planet	E. S. GREW
The Myths of Greece and Rome	H. A. GUERBER
A Study in Stellar Evolution	G. E. HALE
Astronomy	H. JACOBY
Astronomy of the Ancients	SIR GEORGE C. LEWIS
The Evolution of Worlds *Mars and Its Canals*	PERCIVAL LOWELL
A Beginner's Star-Book	KELVIN MCKREADY
The Friendly Stars *The Ways of the Planets*	MARTHA EVANS MARTIN
The Romance of Modern Astronomy	H. MACPHERSON, JR.
The Astronomy of the Bible	E. W. MAUNDER
Descriptive Astronomy	F. R. MOULTON
The Spectroscope and Its Work	H. F. NEWALL
Astronomy for Everybody	SIMON F. NEWCOMB
Star Lore of All Ages *In Starland with a Three-Inch Telescope*	W. TYLER OLCOTT
The Moon	W. H. PICKERING
The Solar System	C. L. POOR
The Stars in Song and Legend	J. G. PORTER
Half-hours with the Summer Stars	MARY PROCTOR
Half-hours with the Stars *A New Star Atlas*	RICHARD PROCTOR

How to Study the Stars	L. RUDAUX
Researches on the Evolution of the Stellar System .	T. J. J. SEE
Astronomy with the Naked Eye *Astronomy in a Nutshell* *Curiosities of the Skies* *Round the Year with the Stars*	G. P. SERVISS
New Astronomy	D. P. TODD
Manual of Astronomy	CHARLES A. YOUNG
The Monthly Evening Sky Map	
Popular Astronomy	
The Observatory	

The Call of the Stars

Part I
The Stars

CHAPTER I

GENERAL REMARKS

The sad and solemn night
  Hath yet her multitude of cheerful fires;
The glorious host of light
  Walk the dark hemisphere till she retires;
All through her silent watches, gliding slow,
  Her constellations come, and climb the heavens, and go.

BRYANT.

On almost any moonless night when the sky is perfectly clear, and the soft shades of twilight have vanished, a most enjoyable half-hour or hour may be spent in gazing upon the immense deep blue expanse above, bedecked with roving planets and scintillating stars. The beautiful constellations—strange groupings of the brighter stars, handed down from the antiquity of the ages—are always present in God's great outdoors, and are ever changing as the months go by, constituting a scene of marvellous and impressive splendour, and at the same time affording an unfailing field for study, of the highest interest and utility.

Besides the stars themselves, a most conspicuous object, varying approximately from five to forty degrees in width, is that wonderful belt of faintly diffused light termed the Galaxy or Milky Way, which, with its rifts and chasms, stretches like a magnificent arch across the constellated sky, and forms the equatorial zone of

the vast spherical or spheroidal universe of stars. Milton in his *Paradise Lost*—the loftiest intellectual effort in the whole range of literature—aptly refers to it as:

> A broad and ample road whose dust is gold
> And pavement stars.

Then, too, the myriads of nebulæ and star clusters in every stage of evolution and the many so-called variable stars, some of which can be seen with the naked eye, are all most interesting objects to the observer who is so fortunate as to possess a small telescope—the ideal instrument for the amateur being a three-inch or a five-inch, equatorially mounted, and provided with eyepieces of proper powers.

Many stellar wonders, it is well known, are revealed by even a large opera-glass magnifying about three or four diameters, and still more by a prism binocular field-glass with a magnifying power of seven or ten or fifteen diameters. An opera-glass will show up fifth- or sixth-magnitude stars quite plainly, and will also bring into vision about ten times as many stars as the unaided eye can see. A small telescope will show stars down to the ninth magnitude, and with the very best telescope the limit of vision is reached at about the sixteenth or the seventeenth magnitude, while stars from the eighteenth down to the twentieth magnitude are recognisable only by means of the photographic plate.

None of the stars present any sensible disk or surface image, even in the most powerful telescopes. They all appear as mere luminous points, a little more or a little less radiant, and are never seen to set, as owing to the terrestrial atmosphere they cease to be visible

before they reach the horizon. It is a remarkable fact that a fixed star seems smaller, though brighter, in a good telescope than when seen with the naked eye, as the irradiation which causes it to appear larger to the naked eye vanishes in the telescope.

The twinkling or scintillation of a star, a phenomenon over which poets in all periods of the world's history have rhapsodised, and of which children have been made familiar by the old nursery rhyme

Twinkle, twinkle, little star,

is due to aërial disturbances by which the progress of light is interfered with. The white stellar light, which consists of all the rainbow colours, is broken up into its elementary colours in passing through the restless terrestrial atmosphere. Proportionate to the aërial density and motion, now one colour prevails over the rest, and now another, so that the star appears to alter its colour and brightness incessantly. The scintillation is especially noticeable on clear wintry nights, being most pronounced in January and February, and has been observed to increase during the time of twilight. It is always large near the horizon, and is apt to be quite marked if a change of weather is imminent. Yellow and red stars seem to twinkle the most, white stars the least.

According to their radiance, rather than to their real size, stellar photometry arbitrarily divides the stars visible to the naked eye into six magnitudes, each magnitude being approximately two and a half times brighter than the next below it in rank. Then, too, each magnitude has been found to be about three times more numerous than the one which precedes it. About twenty of the very brightest stars in the sky, notwith-

standing they show great inequality, are called first-magnitude stars, the star Aldebaran being generally taken as the standard of brightness. About sixty-five, not quite so bright, are of the second magnitude, nearly two hundred of the third, over four hundred of the fourth, about eleven hundred of the fifth, and over three thousand of the sixth magnitude. The total number of stars, therefore, that can be seen without optical aid, is about five thousand, distributed nearly equally between the northern and the southern skies. Not more than about two thousand of these are visible at any one time to the unaided eye.

The stars, however, that can be seen with the naked eye are only the merest handful, compared with the vast number of stars in the entire stellar system. It is said that the great photographic chart and catalogue of the heavens,[1] work on which has extended over many years, will show about forty million stars, and will include all down to the fourteenth magnitude. Nearly one and a quarter million of the brightest of these will be catalogued. Some astronomers, who have attempted to estimate the number of the starry host, declare that if all the stars could be counted, they would exceed one hundred million. But plainly, considering the endlessness of space, it is most probable that even this liberal estimate falls far short of the myriads that actually exist. Bickerton has recently expressed the opinion that there are at least a thousand million suns, vivid and dead, in the entire universe. And again, for all that beings on this earth can tell, every star may

[1] The International Photographic Survey of the Heavens was inaugurated in April, 1887, at a conference of astronomers, representing sixteen different nationalities, which met in Paris, on the invitation of M. l'Amiral Mouchez, a late director of the Paris Observatory.

be the mighty ruler of a system of bodies revolving round it, similar to that revolving round the sun, itself a star.

The old Bible words, "Look now toward heaven and tell the stars, if thou be able to number them," bear forcible witness to their vast multitude. Their actual number is known only to Him who "telleth the number of the stars" and "calleth them all by name."

> Though we too call the stars, they answer not;
> They do not softly come like children shy
> At a fond parent's calling, I wot,
> We do not know what names God calls them by.

For the amateur star-gazer, particular interest will attach to perhaps not over three hundred easily to be distinguished stars, arranged in interesting star-groups, and comprising all of the first, second, and third magnitude stars, and a few of the fourth.

Naked-eye stars, or as they are sometimes termed "lucid stars," are distributed over the entire sky with considerable uniformity, but telescopic stars—those which are invisible without telescopic aid—are most thickly crowded in the Milky Way.

The names and colours of the twenty brightest stars, with their magnitudes, in the order of their brightness, according to the *Revised Harvard Photometry*, 1908, are as follows:

Sirius (bluish white)	−1.6
Canopus (bluish white)	−0.9
Alpha Centauri (white)	0.1
Vega (pale sapphire)	0.1
Capella (creamy white)	0.2
Arcturus (orange)	0.2
Rigel (bluish white)	0.3

Procyon (yellowish white)	0.5
Achernar (white)	0.6
Beta Centauri (white)	0.9
Altair (yellowish white)	0.9
Betelgeux (orange red)	0.9 max. 1.4 min.
Alpha Crucis (bluish white)	1.1
Aldebaran (light rose)	1.1
Spica (silvery white)	1.2
Pollux (orange)	1.2
Antares (bright red)	1.2
Fomalhaut (reddish)	1.3
Deneb (white)	1.3
Regulus (white)	1.3

Three of these brilliant stars—Capella, Altair, and Deneb or Alpha Cygni—are situated very close to the Milky Way. Four others—Vega, Procyon, Betelgeux, and Aldebaran—are located upon its immediate border. Five—Canopus, Alpha Centauri, Beta Centauri, Alpha Crucis, and Achernar—are so far south that they cannot be seen in this latitude, but can be seen in the latitude of Cuba. Canopus and Achernar, which are a little farther north than the others, can be seen in some parts of Florida and Texas.

The stellar magnitude of the sun, which gives ten thousand million times the light of Sirius, is estimated at about −26.5. It has been calculated that on a clear night the total starlight from the entire celestial sphere amounts to about one-sixtieth of the light of the full moon. And yet according to recent statistical research, based on the new chart of the heavens, it is said, that ninety-five per cent. of the stars visible through a fair-sized telescope, are in actual luminosity greater than the sun.

Of all the stars strewn through space, there are but seventy odd whose actual distances have been measured, the others being so remote that no parallax can be found for them. It is possible, however, that as a result of the investigations now in progress, the distances of most of the naked-eye stars will be ascertained ere many years have elapsed. The distances, where known, are usually expressed not in miles, but in what is termed "light years," astronomers having adopted as the unit of stellar distance that celestial yardstick the "light year"—the space travelled by a ray of light in a year, while moving at the rate of 186,400 miles a second—a speed identical with the measured speed of electricity. This amounts roughly to about six million million miles.

The average distance from the earth of first-magnitude stars is about thirty-three light years, that of second magnitude stars, fifty-two light years, and that of third magnitude stars, about eighty-two light years.

At the present time, so far as is known, the brilliant star Alpha Centauri, visible only in southern latitudes, is the nearest of the stars. Careful calculations have fixed its distance at 4¼ light years, or about twenty-five million million miles. A good idea of this great distance may be had by regarding the distance from the earth to the sun, which averages 92,820,000 miles, (107½ times the sun's diameter) as one foot, then Alpha Centauri would be, on the same scale, over fifty miles away. Sound, which is a rather fast traveller, but is dependent on the atmosphere for its motion, would, if it were possible for it to travel through space from this nearest fixed star, spend at its rate of speed—1100 feet a second—over three million years on the journey.

The average distance of Lalande 21185, an incon-

spicuous telescopic star of about the seventh magnitude, in the constellation of the Great Bear, and the nearest star in the northern skies, is, as estimated by different authorities, eight light years, or over 505,000 times that of the sun from the earth.

The radiant bluish-white star Sirius, the nearest of the bright stars in the northern hemisphere, and by far the most brilliant star in the whole sky, though by no means the biggest of the stars, is 8¾ light years distant, or about fifty-two million million miles.

The fourth-magnitude star Tau, in Cetus, the Whale, is estimated to be 9⅘ light years distant.

The brilliant Procyon, a yellowish-white star, and one of the most interesting in the entire heavens, is about ten light years away.

61 Cygni, a relatively little star of the fifth and a half magnitude, in the constellation of the Swan, is, according to latest measurements 10½ light years distant. It was the first star whose distance was measured, and until quite recently was supposed to be only 6⅓ light years away.

The brightest star in the southern skies, second to Sirius out of the entire sky, is a bluish-white star known as Canopus. It is so far off, however, that its distance cannot be ascertained. Roughly, it has been estimated at not less than 325 light years away.

The reddish star Fomalhaut, the farthest south of all the first magnitude stars visible in this latitude, is 23½ light years distant.

The beautiful bluish-white star Vega, called the arc-light of the heavens, a star a hundred times greater than the sun, and which about fourteen thousand years ago was the north polar-star, is thirty-five light years away.

The slightly greenish-white star Castor, one of the Heavenly Twins, and the finest double star in the northern heavens, is nearly 116 light years distant, while his immortal brother Pollux is about fifty-one.

The magnificent orange-tinted star, the flying Arcturus, one of the grandest orbs in the sky, is 43½ light years distant.

A creamy-white star, the merry Capella,—the "star of stars,"—with an estimated diameter of about fourteen million miles, is about forty-nine light years distant.

The rosy Aldebaran, one of the four Royal stars of astrology—the others being Regulus, Antares, and Fomalhaut—is about forty-four light years away.

The silvery Rigel, and the variable, ruddy Betelgeux, leading stars in spectacular Orion, the most magnificent of all the constellations and one of the few visible from all parts of the earth, are so far off that their distances can scarcely be said to be known.

The most famous star-cluster in the heavens, the twinkling Pleiades, sometimes called the "Seven Sisters," referred to in the great drama of Job (which is believed to be one of the oldest books in existence), and admirably pictured in Tennyson's *Locksley Hall:*

Many a night I saw the Pleiads, rising through the mellow
    shade,
Glitter like a swarm of fire-flies tangled in a silver braid

is, according to some estimates, about 250 light years distant. While that "lighthouse in the sky," Polaris the pole star, a star about the size of the sun, and which consists of three suns revolving about a common centre, shines by light which left it nearly seventy years ago.

Then again, the smallest telescopic stars, such as are

seen in that most wonderful feature of the sky, the Milky Way, are believed to be from ten to twenty thousand years of light away. All astronomical measurements, however, fail here, as stars that are more than sixty light years distant are to-day practically beyond the limits of *exact* measurement.

> How distant some of the nocturnal Suns!
> So distant, says the Sage, 'twere not absurd
> To doubt, if beams set out at Nature's birth,
> Are yet arrived at this so foreign world:
> Though nothing half so rapid as their flight.
>
> YOUNG, *Night Thoughts*.

To the ordinary beholder one star seems very much like another, and yet far from being merely the twinkling tiny dots of light they seem to be, the silent stars are suns with retinues unseen, shining by their own inherent light, many of them gigantic suns, so very distant that they appear, not as at the moment of observation, but as they did years ago. The light seen is the "ancient" light that left their surface from a few to scores or even thousands of years back in the past. Some of the stars may even have ceased to exist, but as the last rays they sent out have not yet reached this planet, it may not be known for years or even centuries that a star had become extinct.

> Were a star quenched on high
> For ages would its light,
> Still travelling downward from the sky,
> Shine on our mortal sight.
>
> LONGFELLOW.

It will be noticed by the observer that the stars, "the eternal jewels of the short-lived night," as Mary

Mapes Dodge in *The Stars* calls them, have individual colours, and that the colours are nearly all faint shades. Some of the brighter stars are a brilliant white with a steely glitter, like Sirius. Not a few are golden yellow, like Capella and the sun, while stars of a reddish tone, which ranges from the merest shade up to a fairly deep orange, are not uncommon. Still others have tints of the ruby, the emerald, the topaz, the garnet, and even the sapphire. Dr. Warren, in referring to coloured stars beautifully writes: "We are charmed with the variegated flowers of our gardens of earth, but He who makes the fields blush with flowers under the warm kisses of the sun, has planted his wider garden of space with coloured stars. The rainbow flowers of the foot-stool, and the starry flowers of the throne, proclaim one being as the author of them all." Recalling Pierre de Coulevain's lines in *The Heart of Life*, everywhere throughout the Universe, everything is linked together, and, as Francis Thompson, the English philosopher-poet, aptly puts it:

> Thou canst not stir a flower
> Without troubling a star.

Among conspicuous stars Antares in the heart of the Scorpion is the ruddiest, and Betelgeux in the right shoulder of Orion comes next. Some of the first-magnitude stars, such as Arcturus and others, will be found to have distinct orange tones. So peculiarly favoured by red and orange stars is that portion of the heavens between Aquila, Lyra, and Cygnus that it has not inaptly been styled the Red Region, or the Red Region of Cygnus. White and yellow and orange-red are about the only star colours that are distinguishable with the naked eye. When seen through the telescope

some of the fainter stars seem deep red in colour, while others are of a delicate bluish or greenish cast. Marked influence upon the colour and appearance of the stars, it may be noted, is exerted by the condition of the atmosphere. Bright stars seem most brilliant when near the horizon, while faint stars are best seen near the zenith—the point exactly over the observer's head.

It has been observed that a blue or a green star is never found alone, but usually in company with a red or an orange star, and that bright white stars often have small blue ones in their vicinity. The finest examples of blue or green stars are found in the smaller members of some of the double systems. In the case of the double star Albireo, in the foot of the northern cross in constellation Cygnus, one of the most beautiful objects within the range of small telescopes in the northern sky, the larger star is orange-yellow, and the smaller one is greenish-blue. Sometimes a small cluster of stars will display all sorts of colours. The contrast of a red and a white star in the same field is not infrequently a most vivid and never-to-be-forgotten sight. Then, too, how wondrous must be the colouring observed by the planet-beings, if such exist, in any one of the not improbable planets revolving round such glorious suns! How grand the fairy spectacle in those belonging to the compound systems, one sun setting it may be in golden yellow, or in purest green, and another rising in amethyst blue or in richest purple! Moreover, fancy can sketch better than words can describe, or an artist portray, the richness, beauty, and variety, of the hues presented, when such charmingly coloured suns, mingling their flashing rays, happen together in the sky.

From the infantile nebula, to the star dying of old

age, it will be found that such as are of the same colour are about of the same age, and have much the same composition. Nebulæ that are entirely in a gaseous condition are of a greenish tint, while such as are composed of partially-cooled matter, like the spiral nebulæ, are white in colour. White and bluish-white stars, such as Sirius, Rigel, Spica, and Vega, are young in the order of evolution, and are at full glow. In the course of time, as they reach their hottest stage, they turn golden-yellow like Capella, Pollux, and the sun, and again as they get older, become ruddy or red, and are often variable, as in the cases of Betelgeux, Aldebaran, and Antares. Finally, as the ages pass, their light dies away, and they become dark, opaque bodies —extinct and dead suns rushing unseen on their unlit ways. It has been roughly estimated that the extinct stars or suns outnumber the lucent ones, one hundred to one. Verily, the universe is one vast cemetery of dead suns and systems of worlds. The process of creation or of evolution of matter is, however, continuously going on, suns and star systems are ever being evolved, and as Flammarion puts it, "in space there are both cradles and tombs."

About seventy-five per cent. of the brighter stars are white or bluish-white (sirian stars), twenty-three per cent. are yellowish (solar stars), about one per cent. are orange-red, and one per cent. blood-red. Helium, which is one of the products of radio-active elements, is present in the bluish-white stars, and to it they owe their supreme brilliance, while hydrogen appears extensively in the luminous white stars. Carbon, magnesium, iron, and other metals are present in the solar or yellow stars, and carbon compounds in the redder stars. Recently, it has been found, that under

suitable conditions, the gases helium and neon may be produced by passing an electric discharge through hydrogen.

All the stars are popularly called "fixed" stars, to distinguish them from the planets or "wandering" stars, which are always shifting their positions in the heavens. The name was given them by the ancients, the old idea being that the stars were "fastened like nails to the surface of the sky," and therefore were absolutely fixed and motionless, unchangeable, eternal. Careful observations have shown that not only are they not "fixed" but that they whirl through space in all directions, with a velocity far greater than the swiftest of the planets,[1] and further that far from being unchangeable and eternal, they have had their beginning, and will at some indeterminately remote age reach their end.

> Flowers of the sky! ye too, to age must yield,
> Frail as your silken sisters of the field.
>
> ERASMUS DARWIN.

Yet so distant are they, that, as nearly as the unaided eye can judge, they remain in the same relative positions from age to age. Hence the casual observer of to-day sees them about as the Egyptians saw them when building their pyramids (Plate II) long centuries ago. As another has well said, they watched the earth grow fit for man long before man came, and they will doubtless be shining on, after the human race itself has disappeared from the surface of the planet.

[1] According to recent spectroscopic observations made at Lick Observatory, it has been found that stars in the early stages of their existence travel slowly through space, and that their speed increases with their development.

PLATE II. The Great Pyramid of Cheops
(From the south-east)

In passing it may be remarked that quite often stars which seem to be neighbours in the sky, and to form definite configurations, have no real connection after all. Some are many times as far away as others, and they only seem nearer because they are nearly in line with one another.

The actual motion of a star over the face of the sky, that is to say across the line of vision, is technically known as "proper motion." A star that is moving directly towards or away from the earth has no proper motion, since it does not alter its position on the face of the sky. In measuring the proper or cross motion of a star, the measurement taken is only of that portion of the motion which is across the line of vision, and can be determined by the telescope. Motion which is in the direction of the line of vision, technically called "motion in the line of sight"—"radial velocity" (*vitesse radiale*)—hitherto unascertainable by micrometrical measures with an ordinary telescope, is readily detected by Doppler's method of spectrum observation.

The proper or cross motions of over ten thousand stars have been measured, the first being made out by Halley in 1718, their mean rate being, according to Campbell, twenty-one miles a second. The swiftest known star, a champion racer, is an inconspicuous, eighth-magnitude star in the constellation Pictor in the southern hemisphere. The next swiftest is a sixth-magnitude star, just about the limit of ordinary visibility, in the constellation of the Great Bear, known as No. 1830, in Groombridge's catalogue of circumpolar stars. Its speed is estimated to be 185 miles a second, or six hundred times faster than a cannon-ball flies. In the course of a century it would move over a space equal to a third of the diameter of the full moon, and

in 185,000 years would complete a circuit of the whole sky. It is about ten times as far away as Alpha Centauri, and has sometimes been styled the "Runaway Star."

Arcturus in the constellation Boötes, the Bear Driver, which also has a large proper or cross motion, is travelling with great rapidity toward the south-south-west, and has advanced its position a degree or more since the beginning of the Christian Era.

The pace of one of the earth's nearer neighbours in space, 61 Cygni, is 49½ miles a second, while Mu, a fifth-magnitude star in Cassiopeia, is rushing on at the rate of ninety-eight miles in the same time.

The sun, itself a fixed star, carrying along with it the whole solar system, is advancing at the rapid rate of thirteen miles a second towards the fourth-magnitude star Delta in the middle of the Harp, Lyra. Since the time of Adam the sun has, as Serviss states, led his whole *cortège* of planets and their satellites through the wastes of space no less than 225,000,000,000 miles. Meditating on the star-strewn heavens, the observer may well exclaim with one of old:

> When I consider the heavens, the work of thy fingers,
> The moon and the stars, which thou hast ordained;
> What is man, that thou are mindful of him?
> And the son of man, that thou visitest him?
>
> *Psalms* viii., 3.

There are grounds for assuming that the proper or cross motions of some of the stars have, in the lapse of time, produced marked changes in their brightness, as instanced by the cases of Castor and Pollux. In old catalogues Castor was lettered Alpha and Pollux Beta,

but to-day Pollux stands first, being much the brighter of the two.

Then, too, it has been observed that in a number of instances proper or cross motions of stars appear to take place in groups—a phenomenon known as "star-drift," and the stars as "migrating stars." Many of the stars composing the well-known silvery cluster the Pleiades appear to be drifting through space in the same direction, like a flock of birds, a few somewhat in advance of the rest. Four of the stars forming the W-shaped figure in Cassiopeia, namely Beta, Alpha, Delta, and Epsilon, are moving in an easterly direction and at different speeds, while the fifth star, Gamma, is moving westward. Beta's motion is apparently more rapid than that of the others. And further, five of the stars which make up the striking figure of the capital letter V in the Hyades, are moving in a northerly direction, while two others of the cluster are moving eastward. Aldebaran, the chief star of the cluster and the lucida of Taurus, is apparently the most affected by the easterly motion, and will, as the ages pass, inevitably drift away from its present companions.

The seven principal stars of the beautiful Northern Crown, which are arranged in a semicircle, and outline a perfect crown, have movements in three directions at right angles to one another. They must in consequence eventually drift apart, and in the lapse of time the beautiful figure will have dissolved. Five of the seven stars composing The Dipper are moving in one direction, while the other two—the star at the end of the handle and that one of the "pointers" which is nearer the pole star—are moving in almost an opposite direction. They are between ninety and one hundred light years distant and are travelling at about the same

rate of speed, eighteen miles a second. Thousands of years hence, the aspect of The Dipper will have completely changed; the handle will have become somewhat extended and bent, and the bowl more or less distorted. Flammarion even goes so far as to say that fifty thousand years ago, it had the form of the Swastika cross,—the oldest cross and symbol in the world,—and that fifty thousand years hence it will resemble an exaggerated steamer chair. So too, in the lapse of time, by reason of the stars' proper or cross motion, the most beautiful constellation Orion will have undergone marked alteration in the grouping of its stars. Eventually it may even become merged with the constellations Taurus and Canis Major, into one immense star-group. And, again, some astronomers, including Professor Kapteyn of Groningen, the distinguished Dutch astronomer, have suggested, that a large part of the visible universe is occupied by two vast streams or drifts of stars moving in nearly opposite directions, the supposed line of approach of the intersecting streams—one travelling at the rate of seventeen miles a second, and the other at the rate of five miles a second—being that joining the sun and Xi Orionis, and lying nearly in the plane of the Milky Way. The whole heavens, forsooth, are in rapid transit, and their dislocation is but a question of time.

Investigations into the motions of the larger stars advancing towards or moving from the solar system have shown that Sirius the Dog Star, or, as it has been humorously termed the "sky terrier," the leading star in the constellation of the Greater Dog, is approaching at the rate of five miles a second; Vega in the constellation of the Lyre, at nine; Arcturus in the constellation of the Bear Driver, at three; Altair in the constellation of

the Flying Eagle, at 20½; and the bright star Procyon in the constellation of the Lesser Dog, at 2½ miles a second. Whilst the red star Aldebaran in the constellation of the great Bull is receding at the rate of thirty-four miles a second; Capella the leading brilliant in the constellation of the Charioteer, at 18½; Rigel in the constellation of the Mighty Hunter Orion, at thirty; Castor in the constellation of the Twins, at four; and Pollux, in the same constellation, at two miles a second. It will thus be noticed that while the twin brethren, Castor and Pollux, have been standing apparently side by side, with their feet in the Milky Way, for over forty centuries, they have actually been drifting apart at the rate of over seven thousand miles an hour. Despite their rapid flight, so remote are they that their position with regard to each other, as far as the human eye can judge, has not undergone any sensible change. They still maintain their fraternal relationship, and are apparently as much the Heavenly Twins to-day, as they were in the time of Homer and Hesiod (800 B.C.).

From the earliest times the stars, which to each succeeding age have been a beauty and a mystery, have been divided up into groups known as "constellations." The men of old saw in these groupings, which were extremely irregular in size and shape, the figures of persons, animals, and other objects, fixed on the purple walls of the sky, and naturally called the constellations after them. The practice of giving names and shapes to the star-groups, in which imagination was a most potent factor, is generally supposed to have originated on the Euphrates. A few of the groupings bear vague resemblance to the objects from which they are named, but in the majority of instances the

likeness is purely fanciful. Many of the constellations appear to have been invented for the purpose of immortalising the heroes, heroines, and fabled beasts of mythological lore. Imperfect as they are, the old pictures and groupings are still retained, not only for convenience in finding the individual stars, but also on account of the confusion that would arise were they now abandoned. Besides, they are of too much historical value to admit of their ever being discarded.

And thus the stars
At once took names, and rise familiar now.
EUDOXUS.

Quoting from Burr's tribute in *The Stars of God:* "Celestial antiquities, we salute you, and through you most reverently that Ancient of Days from whom you come and on whose errands you go."

The earliest description of the sky on record is contained in the Φαινόμενα, a celebrated astronomical poem, by Aratus of Soli (271 B.C.), court physician to Antigonus Gonatas, King of Macedonia. It consisted of 732 verses, and was a versification of the prose work of Eudoxus of Cnidus in Asia Minor, which was based upon observations of the heavens made probably by Chaldean astronomers fifteen centuries before. It may here be of interest to note that Aratus is the poet referred to by St. Paul, when in his sermon on Mars Hill, he tells the novelty-loving Athenians (Acts xvii., 28), that "certain also of your own poets have said, For we are also His offspring" (fifth line of the Φαινόμενα).

A word may be said here concerning duplication of stellar figures, which is, as mentioned by Olcott, not uncommon. In many cases two figures are found in

close proximity, as, for instance, the figures of two Bears, two Dogs, two Fishes, two Lions, etc. Then again, there are two Crowns, two Streams, two Goats, as well as several Serpents, Giants, and Birds. And further, many of the constellations, it will be noticed, are closely connected with neighbouring figures, as, for instance, the gallant Perseus with upraised sword rushing to the rescue of the fair Andromeda, the Mighty Hunter with his starry club threatening the advancing Bull, the Scorpion attempting to sting Ophiuchus as he is crushing the Serpent in his hands, Aquarius pouring water from an urn into the mouth of the Southern Fish, and the wonderful Archer forever aiming a shaft at the heart of the famous "Stinger," the reputed slayer of Orion. Then, too, the Herdsman's hounds are observed following and harassing the Great Bear, the Water-Snake pursuing the Lesser Dog, and the timid Hare fleeing before the Dogs of Orion; while in the so-called great celestial sea, numerous marine creatures are seen, such as the Whale, the Dolphin, the Fishes, the Sea-Goat, the Crane, and the Southern Fish.

The number of constellations formed by the ancients is forty-eight, while about forty have since been added. Of these, sixty-seven are now recognised as in ordinary use. Fifty-eight of the more noticeable ones are embraced in this book. Twelve of them follow one another along the ecliptic and bear the same names as its signs. The names of the different constellations will be found on the charts, where also, it will be observed, the more important stars of a constellation have been linked up by dotted lines.

Owing to the yearly motion of the earth around the sun, the stars rise and set nearly four minutes (3m. 56s.) earlier each successive evening, and thus, roughly

speaking, they are always "four minutes fast." Besides, the sun appears to gain steadily upon the stars, so that stars seen in the south at one time of the year, because they are opposite the sun, are invisible six months later on account of the brightness of the sunlight. It will thus be noticed that as four minutes of time correspond to one degree of space measured on the face of the sky, the aspect of the heavens changes from night to night by reason of the shifting of the constellations about one degree westward every twenty-four hours. And further, that in the course of a year the revolution is completed and the stars are observed in precisely the same places they occupied a year before. Thus the stars that are seen on summer nights this year will be seen on summer nights next year, and the year after, and for ages to come.

About one hundred of the brighter stars have received individual names. Many of the first-magnitude stars have proper names of Greek or Latin origin, while some are Arabic. Most of the smaller ones have Arabic names. Then, too, the chief stars in any constellation are designated by the small letters of the Greek alphabet. Thus the best star in Cygnus, the Swan, is α Cygni—the Alpha star of the constellation Cygnus; the next β Cygni, and so on.

The brightest stars are usually spoken of by their individual names, but the less important stars are referred to by either their proper or family names; as Alpheratz or α Andromedæ, Caph or β Cassiopeiæ, Hamal or α Arietis.

And again, the stars are designated by a system of numbers, such as Flamsteed assigned, arranged usually in the order of right ascension, without regard to their brilliancy.

The general practice among astronomers of to-day has been to identify the stars that bestrew the sky, not so much by their names as by their numbers in some well-known star-catalogue of their positions in right ascension[1] and declination, corresponding to terrestrial longitude and latitude. But for the ordinary observer, it may be said, that an intimate acquaintance with constellation figures and stellar names will have much more of interest than ordinarily attaches to a technical description by star numbers. The statement that a star is situated right ascension 5 hrs. 50 m. 30.94 s., north declination 7° 23′ 30.83″ (mean place Jan. 0.49 day 1914), is enough perhaps for the professional astronomer; but for most people, if not for all, it is better to call it Betelgeux in the constellation of Orion.

Of the several imaginary great circles considered by astronomers as drawn in the heavens, one very convenient circle of reference is the *ecliptic*. It is the great circle indicating the *apparent* annual path of the sun eastward among the stars; the extension outward to the starry sphere of the plane in which the earth moves round the sun. Astronomically speaking it is as definite a circle or line as is the horizon, and is called the ecliptic because eclipses can happen only when the moon is on or very near that curved line. It is inclined to the celestial equator or equinoctial, which is a projection of the terrestrial equator extended toward the stars, at an angle of about 23½°. Milton accounts for the

[1] *Celestial* longitude, as distinguished from right ascension, is distance from the vernal equinox, reckoned eastward, along the *ecliptic*, and is expressed in degrees instead of hours. *Celestial* latitude, as distinguished from declination, is distance north or south of the *ecliptic*. For most purposes, it may be said that equatorial and polar measurements are the most convenient.

obliquity, as if by direct interposition of the Creator, thus:

> Some say he bids his angels turn askance
> The poles of earth twice ten degrees or more
> From the sun's axle; they with labour push'd
> Oblique the centric globe; some say, the sun
> Was bid turn reins from th' equinoctial road
> Like distant breadth to Taurus with the seven
> Atlantic Sisters, and the Spartan Twins,
> Up to the Tropic Crab; thence down amain
> By Leo and the Virgin, and the Scales,
> As deep as Capricorn, to bring in change
> Of seasons to each clime.

The crossing points of the celestial equator and the ecliptic, during the year, are respectively the vernal and the autumnal equinox, while the points midway between these, where the tropics touch the ecliptic, are respectively the summer and winter solstice. The line of the ecliptic is north of the equator from the vernal to the autumnal equinox, and south of it from the autumnal back to the vernal equinox.

There is, furthermore, an imaginary zone or belt encircling the heavens, extending about eight degrees above and below the ecliptic, called the *zodiac*. It is of very great antiquity, having originated, it is commonly believed, in archaic Euphratean astronomy. It is called the zodiac because the constellations in it, with the exception of Libra, are all figures of animals. By some it has been humorously styled the "zoölogical garden of the sky." It is the area or space within which the sun, moon, and all the planetary bodies, except some of the planetoids, appear to perform their annual revolutions.

At an early date the ecliptic and consequently the zodiac was divided into twelve parts of thirty degrees each, called *signs* of the zodiac, referred to in the Book of Job, seventeen centuries before the Christian Era, under the name of *Mazzaroth*, along with the Pleiades, Orion and the Bear. Each of these signs coincided roughly with a constellation after which it was named, and has retained its symbolic title to this day. The twelve zodiacal constellations are believed to be the ones spoken of in the astronomical Psalm — the xixth — as being "a tabernacle for the sun."

It is perhaps of interest to note that early in the eighth century, the Venerable Bede, an eminent historian of the early English church, endeavoured to substitute eleven of the apostles for the early signs, Peter taking the place of the Ram, and John the Baptist appropriately taking that of Aquarius to complete the circle. Also, that in the seventeenth century the astronomers Bartsch and Schiller both endeavoured to substitute the Apostles for these time-honoured zodiacal figures, while Sir William Drummond vainly tried to turn them into a dozen Bible patriarchs. And further, that Weigel of the University of Jena proposed that a series of heraldic constellations be formed, the zodiac being composed of the arms of the twelve foremost families of Europe. It is unnecessary, perhaps, to state that all these attempts to displace the old and popular constellation names failed utterly.

The names of the twelve signs of the zodiac beginning at the vernal equinox and passing eastward are familiar to everyone from the well-known English memory verse:

The Ram, the Bull, the Heavenly Twins,
And next the Crab, the Lion shines,
The Virgin and the Scales.
The Scorpion, the Archer, and Sea-Goat,
The Man that pours the Water out
And Fish with glittering tails.

The spring signs are Aries, Taurus, and Gemini; the summer signs are Cancer, Leo, and Virgo; the autumn signs are Libra, Scorpio, and Sagittarius; and the winter signs are Capricornus, Aquarius, and Pisces.

The motion of the north celestial pole around that of the ecliptic occasioned by the attraction of the sun and moon upon the earth at the equator—the position of the celestial poles being dependent upon that of the earth's poles—causes what is known as the *Precession of the Equinoxes*. This phenomenon, discovered by Hipparchus, the father of observational astronomy, while at work on his celebrated catalogue two thousand years ago, is the slow westward movement of the equinoxes along the ecliptic, at the rate of about fifty seconds a year, one degree in seventy-two years, or a sign in 2150 years. At the time the constellations were named the equinoctial points were in the constellations Aries and Libra, but by reason of the precession of the equinoxes they have retrograded nearly a whole sign, and are now in the constellations Pisces and Virgo. Hence, while the vernal equinox, sometimes called the "Greenwich of the Sky," the passage of the sun through which betokens the opening of spring, is in the sign Aries, this sign now corresponds to the constellation Pisces, and will soon pass to Aquarius. The name, "first point of Aries," is, however, still applied to it by time-honoured usage. In a period of about 25,800 years, the equinox

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PLATE III. The Long Slant Passage of the Great Pyramid

ought to have visited all the constellations of the zodiac, and the signs should have backed entirely round the circle of the ecliptic.

Another effect of this gyratory motion of the north celestial pole—like that of some mighty top—around that of the ecliptic, describing a circle whose radius is 23½ degrees, is a change in the pole star. The star Polaris, the most observed of all stars, long known as the North Star, will not always hold this post of honour. It is now about 1¼ degrees from the true pole, around which, notwithstanding it seems stationary in the heavens, it describes a small but appreciable circle. This distance will gradually diminish until about the year 2100, when it will be less than half a degree, after which Polaris will slowly recede from the pole. In about 5600 years, Alderamin or Alpha Cephei will occupy the position of pole star; in seven thousand years the fine and comparatively young star Deneb or Alpha Cygni; and in 11,500 years the brilliant star Vega. It may not be without interest to note, that when Vega becomes the north polar-star, the brilliant Canopus—Mohammed's star—in the southern constellation Argo Navis will be sufficiently near the southern pole of the heavens to serve as a south polar-star.

Some forty centuries ago, Thuban was the pole star, to better view which, the slant northward-pointing passage in the Pyramid of Cheops is supposed to have been built (Plate III.). In about twenty-one thousand years it will again mark the pole of the heavens, and be succeeded once more in office by Polaris, the entire period of revolution being about 25,800 years.

NOTE.—The three pyramids of Gizeh—the Pyramid of Cheops, the pyramid of Chephren (Cheops' brother), and the pyramid of Mycerinus (Cheops' son)—are situ-

ated near the western bank of the Nile about eight miles from Cairo, in latitude 29° 58′ 51″. They stand, not far apart, on a line from north-east to south-west, on an elevated plateau of four hundred acres, about 150 feet above the level of the desert. Nearby is the Great Sphinx carved out of a knob of natural rock, and recently discovered to be hollow, the body representing the body of a lion, and the head a portrait of Pharaoh Chephren. North and south are groups of pyramids, temples, and tombs, while to the westward stretches the vast Libyan Desert.

The Great Pyramid of Cheops (Plate II.), sometimes known as the East Pyramid, is situated on a platform of rock, close to the verge of the elevated plateau, and covers nearly thirteen acres. Its four sides face the cardinal points of the compass. It is now about 450 feet high, and its square base measures 746 feet on a side. The steps, which are said to number 208, are about the height of an average table. The only entrance (as in most of the pyramids) is on the northern face, about 50 feet above the ground. The entrance passage of 3½ by 4 feet, slants at an angle of 26° 41′, and leads down this steep incline through the solid rock for a distance of about 380 feet, to a small subterranean chamber, 96 feet underground. When viewed from the bottom of the tunnel the mouth appears but little larger than the moon's apparent diameter. The observer within looking out of the tunnel is about in line with the pole star, and it is commonly supposed that the object for which the tunnel was built, was to enable the Egyptian astronomer-priests to better observe the pole star of Cheops' time, when at its lower culmination.

After penetrating over 60 feet within the pyramid

the entrance passage connects with an ascending branch passage, about 110 feet long, at an angle of 26°, leading to a landing from which lead two passages. One passage about 126 feet long, running horizontal, connects with the queen's chamber (17 by 19 feet, and 20 feet high), which is almost in the centre of the pyramid, 67 feet above its base. The other passage leads upwards, and opens into a grand gallery 28 feet high, 7 feet wide, and 162 feet long, which opens into the several chambers composing the royal sepulchre.

The king's chamber, which is built in the axis of the pyramid, 131 feet above the ground, is a plain bare room, thirty-four feet long, sixteen feet wide, and twenty feet high, lined with highly polished red granite. It contains only an empty sarcophagus of red granite, the mummy of the king and the funeral equipment having disappeared when the pyramids were ruthlessly opened and plundered by the Arabs.

CHAPTER II

THE NIGHT-SKY OF SPRING

> Roll on, ye Stars! exult in youthful prime,
> Mark with bright curves the printless steps of time.
>
> ERASMUS DARWIN.

IN the onward procession of the year, from equinox to equinox, each of the seasons has its own characteristic groups of stars. The constellations Leo, Virgo, and Boötes, that foreshadow the advent of spring, are as much a part of the vernal season as are the earliest verdure, the buds, the blossoms, and the birds. Their stars have an entirely different individuality from those stellar gems that shone resplendent in the winter sky, or from those softly glowing stars that herald the near approach of gay summer, when, in the words of eloquent Serviss, "the starlight falls without a ripple in the languid air."

There is in fact, it may be observed, a spring sky, a summer sky, an autumn sky, and a winter sky, each possessing a charm and interest peculiarly its own. Longfellow was doubtless thinking of the flowery spring-time when in *Evangeline* he wrote:

> Silently one by one, in the infinite meadows of heaven,
> Blossomed the lovely stars, the forget-me-nots of the angels.

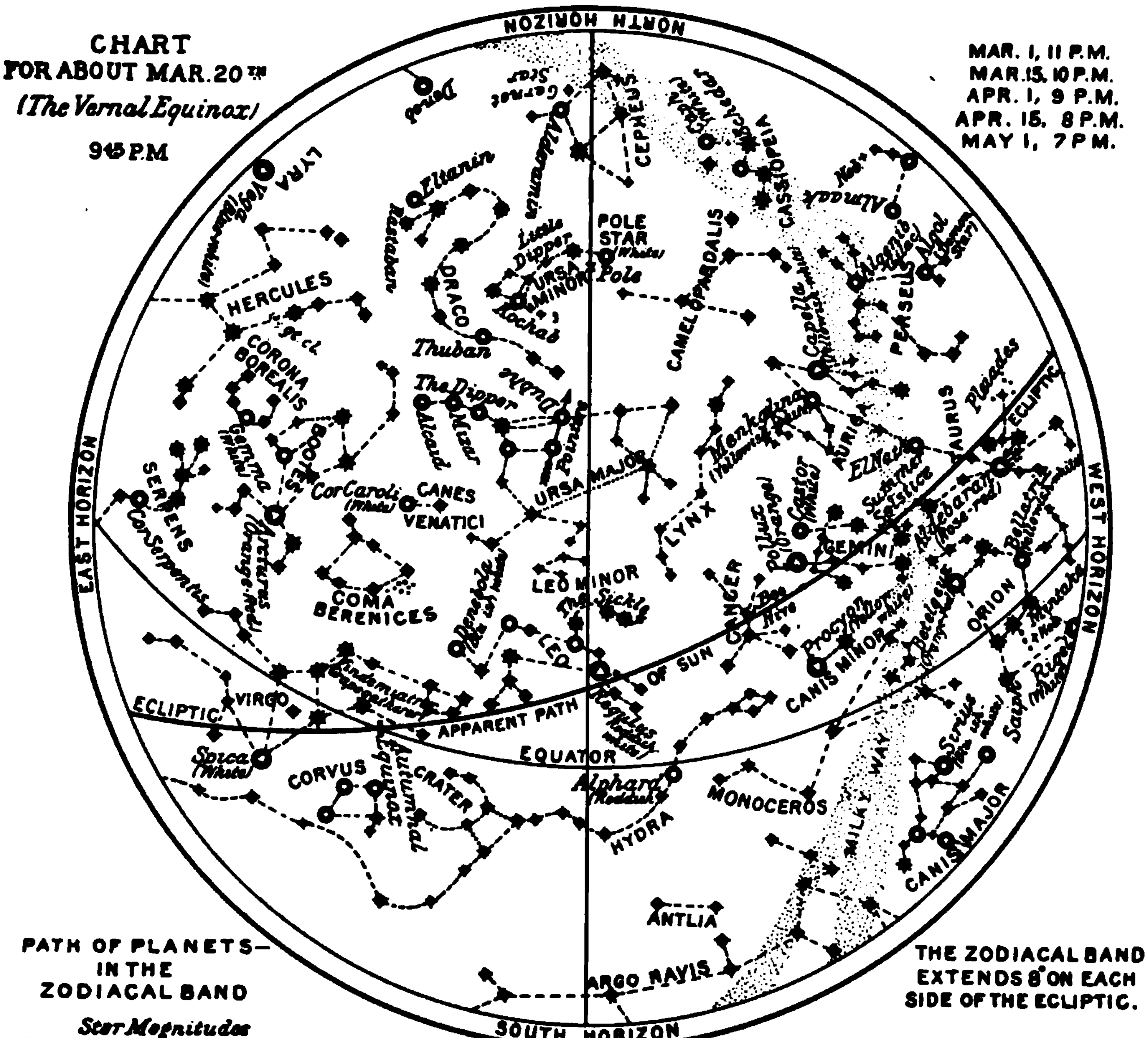

CHART 1—SPRING NIGHT SKY

It makes no difference at what calendar record the year commences; so far as the seasons and constellations are concerned, it begins when the trees begin to bud, the grass to grow, and the earth wakens out of its winter sleep. So following nature's rule in the succession of the seasons, as well as an old English custom abandoned since the middle of the 18th century, the opening of the year, for the purposes of this book at least, will be reckoned as taking place when the sun transits the equator about the 21st of March—the epoch of the vernal equinox—instead of on the 1st of January, as fixed by statute.

The return of spring and the annual rejuvenation of earth have been hailed with delight in all ages of the world. The kingly poet sang thus alluringly of it:

> For, lo, the winter is past,
> The rain is over and gone;
> The flowers appear on the earth;
> The time of the singing of birds is come.
>
> *Solomon's Song* ii., 11–12.

In Persia it has been celebrated for some six thousand years by the "Feast of Novrooz," as a time for general rejoicing, first observed by Jamshyd, the fourth king of the Pishdadian dynasty, whose glory was sung by Sor-âdi and Omar Khayyam. Then, too, it was in the spring-time of creation that the morning stars sang together, and the sons of God shouted for joy. It was spring when Pippa, from the silk mills, passed with her lilting carol—a New Year's day at Asolo in the Trevisan, but spring here:

The year's at the spring
And day's at the morn;
Morning's at seven;
The hillside's dew-pearled;
The lark's on the wing;
The snail's on the thorn:
God's in his heaven—
All's right with the world!

ROBERT BROWNING.

The aspect of the night-sky at the various seasons of the year is represented on the four charts in the body of the book, which also in their entirety trace the annual course of the stars and constellations. The relative positions of the celestial equator, the ecliptic, and the horizon, as also of the equinoctial and solstitial points, are all shown on the charts.

Chart I represents the appearance of the night-sky at about 9:45 P.M. on the 20th of March, about 11:00 P.M. on the 1st of March, 9:00 P.M. on the 1st of April, 8:00 P.M. on the 15th of April, and about 7:00 P.M. on the 1st of May. Then, too, a change of several days, either forward or backward from the dates here given, alters but little the correspondence of the chart with the sky at the hours stated. For, as noted in the previous chapter, the stars rise not quite four minutes earlier each evening, and so the daily westward shift of the entire sky measures but a degree. And, further, the chart is equally applicable at other night-hours in subsequent months of the year, allowing always that the alteration in the position of the stars amounts in a month to two hours. The same statement may be made relative to each chart.

In matching the charts with the sky, it should be remembered that the centre of the chart corresponds

to the zenith (the point directly overhead), and the outline of the chart represents the natural horizon. Also that the observer is supposed to be facing north or south along the meridian, which is an imaginary circle on the celestial sphere, drawn through the zenith and the celestial poles. A star or other celestial body when crossing the meridian is equidistant from its rising and setting points, and is said to be at the point of culmination. Two culminations take place daily, one above and the other below the pole. The former is called the *upper*, and the latter the *lower* culmination. The upper culmination of the sun occurs at noon or mid-day, apparent solar time, and that of the full moon at midnight. And again, a star is said to *transit* when it crosses the meridian. Every star transits due north or south. When stars transit together or within a few minutes of each other, they are known as "simul-transit" stars. In this connection it may be mentioned that it is when the stars are on the meridian that they are in the most favourable position for observation and identification.

The observer, whether facing south or north, should hold the chart over the head, remembering always to have its north, south, east, and west points properly placed. An easy general view of the heavens may be obtained by lying on the back with the head to the north, when the sky may be readily compared with the chart held overhead. Then again, as suggested by Serviss, a mirror held on the lap will be found a great convenience in studying the constellations which are almost or directly overhead.

About the only outfit the sky-student really requires to view the sky, is the proper chart, a pocket electric flash-light with which to examine the chart, and perhaps

a good, strong opera-glass, or field-glass, or a small telescope. There may be times, however, when a pocket compass will prove of service in indicating where true north is. To many, a revolving planisphere, such as the Barritt-Serviss Star and Planet Finder (Fig. 1), may be found useful.

Fig. 1. The Barritt-Serviss Star and Planet Finder.

The beginner is apt to be somewhat confused, at first, by the planets or "wandering" stars, which move about through the zodiacal constellations. He will, however, soon come to know them by their greater apparent size, their peculiar movements, and their tranquil light. The dull red-yellow glare of Saturn, the soft luminosity of Venus, the steady brilliance of Jupiter, the bright ruddy light of Mars, and the rosy lustre of elusive little Mercury, serve to easily distinguish them from the fixed stars.

Ursa Major

(The Greater Bear)

If the observer is viewing the vernal sky at about 10:00 P.M. on the 20th of March, 9:00 P.M. the first week of April, or 8:00 P.M. the middle of April, he will notice in the northern central portion of the heavens the best known and most important of the constellations, Ursa Major, the Greater Bear. And it requires no great effort of imagination to see the monstrous beast striding westward across the sky, with Boötes and his hounds in perpetual pursuit. It is easily recognisable by its

seven principal stars, six of which are of the second magnitude, and one of the third, which when linked together form the remarkable figure familiarly known as The Dipper, or the Big Dipper. It is always, either wholly or partly, above the horizon at and north of the latitudes of New York and Chicago, and can, along with the other circumpolar constellations, Draco, Cepheus, Cassiopeia, Camelopardalis, and Ursa Minor, be seen on any clear night throughout the year, revolving close to the pole star.

> . . . round and round the frozen Pole
> Glideth the lean white bear.
>
> R. W. Buchanan.

That the stars in these circumpolar constellations are not seen by day, is simply due to the fact that the sun-light blots them out.

In *The Ancient Sage*, Tennyson alludes to them as

> . . . some that never set, but pass
> From sight and night to lose themselves in day.

Ursa Major contains over one hundred and thirty visible stars, of which six are of the second magnitude, eleven of the third, and a number of the fourth and fifth, while twenty of the brightest have received individual names. It extends over a considerable portion of the northern sky, a little less than one quarter of its space being occupied by The Dipper. It is bounded on the north by Draco and Camelopardalis, on the east by Canes Venatici, on the south by Leo Minor, and on the west by Lynx and Camelopardalis.

The figure of the bowl of the dipper marks the flank of the Bear, and its handle, which is about twelve

degrees in length, represents its "impossible" tail. The stars Alpha and Beta Ursæ Majoris, commonly known as Dubhe and Merak, the two stars which form the front edge of the bowl, are the most popular of the seven stars of The Dipper. They are often called "pointers," because they are almost directly in line with Polaris, a second-magnitude star at the tip of the Lesser Bear's tail, which marks with fair accuracy the north pole. It is said that Tennyson's sight was so short that, without optical aid, they appeared to him as "two intersecting circles, like the first proposition in Euclid."

The distance between the pointers is about five degrees, hence they may be advantageously employed by the observer as a rough measuring stick with which to estimate celestial distances. The distance from Dubhe to the pole star is about five times that between it and its associate pointer Merak. The distance between the two stars Dubhe and Megrez in the brim of the bowl of the Dipper is about ten degrees. It may here be of interest to note that there are three standards of measurement provided in the heavens. The length of the belt of Orion is three degrees; the distance from Merak to Dubhe is five degrees; and the average apparent diameter of the moon is half a degree. Then, too, any object that appears half a degree in diameter is about 114 times its own height or breadth, away.

The set of bright stars that form The Dipper has been long associated in name with other objects to which it seems to bear some resemblance. In England, it is generally styled the "Plough," or at times "Charles's Wain" from its fancied resemblance to a waggon drawn by three horses tandem. The early Christians regarded it as the "Bier of Lazarus," the

three stars in the tail of the Bear, representing Mary, Martha, and Mary Magdalene. The people of the far north, the Eskimos, imagined it to be a reindeer; while to the Druids it was known as "Arthur's Chariot."

Sir Walter Scott thus alludes to it in the *Lay of the Last Minstrel:*

> Arthur's slow wain his course doth roll
> In utter darkness round the pole.

It is quite likely that this group of stars, and not Arcturus, the leading brilliant in Boötes, is what is referred to in one of the questions which the Lord addressed to Job out of the whirlwind:

> Cans't thou guide Arcturus with his sons?

As translated in the Revised Version the passage reads:

> Cans't thou guide the Bear with her train?

The four stars making the bowl of the dipper, it has been thought, represent the Bear, and the three handle stars, the cubs following in her train.

According to legend the Greater Bear was Callisto or Helice, a nymph, the daughter of Lycaon, King of Arcadia, who, by reason of her beauty, incurred the jealous wrath of Juno, the queen of heaven. Jupiter, to protect Callisto, who was Juno's attendant, from injury at the hands of her mistress, transformed her into a bear. Arcas, Callisto's son by Jupiter, when out hunting, not recognising his mother, was about to slay her with his uplifted spear, when Jupiter, in pity, changed him into a little bear (Ursa Minor), and placed him and his mother among the stars. In Addison's translation of Ovid's *Metamorphoses*, it is stated that Jove

> snatched them through the air
> In whirlwinds up to heaven and fixed them there:
> Where the new constellations nightly rise,
> And add a lustre to the northern skies.

It is further related by an old writer, Dr. Thomas Hood, that as Jupiter swung the bears up into the sky, their tails stretched, and the abnormal length of these most un-ursine appendages is thus happily accounted for.

The Bear, which possesses many interesting features, will be found a great help in locating adjacent constellations, and has been long important as marking the seasons. In spring evenings the seven stars forming The Dipper, which, it is said, exceed the sun in brilliancy from thirty to one hundred and twenty times, are almost directly overhead, with the handle of the dipper pointing towards the east. In summer evenings they are in the north-west, with the handle pointing upwards. In autumn evenings they are low down on the north horizon, with the handle pointing towards the west; while in winter evenings they are seen toward the north-east, with the handle pointing downward. On March 21st, the simul-transit pair of stars, Merak and Dubhe, transit—that is, cross the meridian—at about 11:00 P.M., and at about 11:00 A.M., at lower culmination, on September 22d.

The Dipper swings with a slow revolving motion in a direction contrary to the hands of a clock, right around the pole every twenty-four hours, and in early times served as a sort of celestial timepiece, requiring neither winding nor repairing. During the period between twilight and dawn, the gigantic hour hand of this illuminated clock, formed by an imaginary line

drawn through the pointers to the pole star, will be found to have swung more than half-way round.

Shakespeare, in *King Henry IV.*, well illustrates its use as a timekeeper, when he makes the first carrier at the Rochester Inn yard, exclaim, as he enters with a lantern in his hand:

> Heigh-ho! an it be not four by the day, I'll be hanged:
> Charles' Wain is over the new chimney, and yet our horse is not packed!

Tennyson in his well-known *New Year's Eve*, has a similar allusion:

> We danced about the Maypole, and in the hazel copse,
> Till Charles' Wain came out above the tall white chimney-tops.

Dickens, in *Hard Times*, Book III., chap. 6, it will be remembered, has a scene in which the *apparent* motion of the stars from east to west every twenty-four hours, seems to be ignored. In his description of the accident to, and death of, Stephen Blackpool, a poor fellow who fell into a disused pit called Old Hell Shaft and broke his leg, he comforts the sufferer during his seven days and nights of agony at the bottom of the pit, by a beautiful star shining brightly down upon him *unceasingly*. In the unfortunate man's own words: "Often as I come to myseln, and found it shining on me down there in my trouble, I thowt it were the star as guided to Our Saviour's home. I awmust think it be the very star!" Poor old Stephen, alas! gazing up through the pit-mouth, could, at best, have caught only a glimpse of it for a few moments as it passed across the zenith.

It is said that in ancient times the mariners of Greece used the stars of the Greater Bear, the most beloved of star-groups, as their guide in navigation, while the Phœnicians steered by Polaris the lucida of the Lesser Bear. Manilius, an astronomer-poet of the century preceding the Christian era, thus writes:

> Seven equal stars adorn the greater Bear,
> And teach the Grecian sailors how to steer.

Homer, in the fifth book of the *Odyssey* (Wm. Cowper's tr.), relates that Ulysses was directed by the lovely goddess Calypso, to

> hold the Bear, called else the Wain,
> Continual on his left through all his course,

that is, to steer his raft due east.

Cardan, an astrologer-physician of the sixteenth century, it is said, held that particular stars influenced particular countries, and that the fate of the greatest kingdoms of Europe was determined by the tail of Ursa Major. Butler, in *Hudibras*, thus wrote:

> Cardan believed great states depend
> Upon the tip o' th' Bear's tail's end.

The white star at the end of the "handle of The Dipper," or "tail of the Bear," has been designated Alcaid or Eta or Benetnasch, the chief of the mourners. It is of the second magnitude, and marks the radiant point of the Ursid meteors of November 10th.

Mizar or Zeta, the brilliant white star at the bend of the handle, and about seven degrees from Alcaid, is the most interesting of all the stars of The Dipper. It is one of the finest double stars, its companion being a

bluish telescopic star of the eighth magnitude. In a small telescope it is a very pretty sight. The two components are about 14.6 seconds of arc apart. The brighter component was found by E. C. Pickering in 1889, by means of the spectroscope, to be itself double, the pair revolving about a common centre of gravity in a period of about twenty and a half days. Alcor, apparently close by, and yet distant from it by about one-third the apparent diameter of the moon, forms with it a beautiful naked-eye double and a connected system. These two stars are sometimes styled "the Horse and the Rider." Alcor, the little "Rider-Star" or the "Cavalier," was in olden times regarded as a test for good sight. It has recently been ascertained to be a spectroscopic binary.

Mizar is particularly interesting as being the first telescopic double ever discovered, and was also the first double star to be photographed, and the first star discovered to be again double by the spectroscope. Its quadruple system is about ninety-nine light years distant, has a proper or cross motion of eleven and a half miles a second, and is approaching the solar system at the rate of eight miles a second.

Alioth or Epsilon, the third star in the handle, about four and a half degrees toward the bowl from Mizar, is a spectroscopic binary. It indicates very nearly the radiant point of the Ursid meteors of November 30th. A few degrees south of it, and about seven degrees north of Cor Caroli, is a wonderful, brilliant red star, faintly visible to the naked eye, known as La Superba, which is the brightest star of its class in the sky. The three stars, Alcaid, Mizar, and Alioth, constitute the handle of the dipper.

The pale-yellow star in the rim of the bowl at the

junction of the handle, about five and a half degrees from Alioth, is called Megrez or Delta. It is the smallest and faintest of the seven stars of The Dipper. Both it and the star Caph, or Beta Cassiopeiæ, are in the equinoctial colure, nearly opposite each other, and about equidistant from the pole. The colures, it may be stated, are two imaginary great circles of the celestial sphere at right angles to each other: one, called the *equinoctial colure*, passes through the celestial poles and the equinoxes; the other, termed the *solstitial colure*, passes through the celestial poles and the solstitial points. They divide the ecliptic into the four seasons of the year. Megrez is on the meridian at 9 P.M., May 10th.

The star in the bottom of the dipper, toward the handle, is called Phad, or Gamma. It is of a topaz-yellow colour, and is about four and a half degrees from Megrez.

The greenish-white star in the bottom of the dipper, on the outer edge, about eight degrees from Phad, is known as Merak or Beta. It is a star of the sirian type, and is also a spectroscopic double. A few degrees from it is situated the so-called Owl Nebula (Plate IV.) the largest and finest of the planetary nebulæ.

Dubhe or Alpha, the yellowish star on the farther side of the rim, five degrees from Merak, and ten from Megrez, is the only star in The Dipper that is of the solar type. It has an eleventh-magnitude companion, and is the nearer of the "pointers" to the pole star. It was the orientation point of the temple of Hathor at Denderah. The four stars, Dubhe, Merak, Phad, and Megrez, form the bowl of the dipper, and the hind quarters of the Bear.

Almost directly overhead, between "The Dipper"

and the "Sickle" of Leo, and about fifteen degrees apart, are the three plantigrade paws of the Bear. The right fore-paw and the hind-paw are each marked by two fairly bright stars; while a similar pair nearly in line with them indicates the left hind-paw. The larger star in the right hind-paw is of importance as being the first binary whose orbit was computed. The head of the Bear is marked by a curved row of dim stars a few degrees beyond the bowl of the dipper.

Away round in the north-west is a group of stars known as Cassiopeia or the "Lady in the Chair." It is a companion to The Dipper, and is about opposite to it, as both swing round the axis of the sky. It lies on the course of the Milky Way, and is readily recognised by the irregular W-shaped figure formed by its five chief stars. Along with Cepheus, an inconspicuous but highly interesting group, made up of a few faint stars arranged somewhat in the form of the letter K, and the long, dim, straggling Camelopardalis, it will be better studied at another season.

Ursa Minor
(The Lesser Bear)

Ursa Minor, the Lesser Bear, is a small constellation containing the north pole of the heavens, around which its stars *apparently* revolve from east to west every twenty-four hours. It is surrounded by Draco, Camelopardalis, Cassiopeia, and Perseus, and contains about thirty stars, two of which are of the second magnitude, one of the third, and a few of the fourth and fifth.

Lowell in *Prometheus* alludes to it as

> The Bear that prowled all night about the fold
> Of the North Star.

In the earliest ages, it was differently regarded as the "Little Chariot," the "Waggon of Joseph," and the "Bear that David slew." By the Greeks it was called "Phœnice," because it was the guide of the Phœnicians during their excursions in the Mediterranean, and to the Romans it was known as "Cynosura," or "Dog's Tail."

The seven principal stars of this constellation form a half-sized replica of The Dipper in Ursa Major, and hence are commonly called the Little Dipper. The handle, however, of this tiny dipper is turned in the contrary direction, and the bowl hangs nearly over the star Thuban in Draco, a second-magnitude star just above the handle of The Dipper. The lucida or Alpha star of Ursa Minor is a standard second-magnitude star at the end of the handle of the Little Dipper, or the end of the tail of the Lesser Bear, called Polaris, the north-polar star, the best known and most practically useful of stellar objects. Its position in the sky, about forty-two degrees from the horizon, or a little less than half way from the horizon to the zenith, is pointed out by the direction of the two "pointers" Merak and Dubhe in Ursa Major. Besides, an equilateral triangle having as its base the line joining either Arcturus and Regulus (on the right), or Vega and Arcturus (on the right), will have Polaris near its apex. Moreover, any pair of "simul-transit" stars are of service as pointers to the pole. In fact the two "pointers" in Ursa Major, already referred to, are merely convenient pairs of "simul-transit" stars, just as are Capella and Rigel, Pollux and Procyon, or Markab and Beta Pegasi. Then, too, on a line from Polaris to Mizar, about a degree and a fifth from the former, is situated the true north pole of the heavens. It is indicated on the chart by a small cross near to Polaris.

Sir Thomas Browne, in his *Religio Medici*, has the following quaint reference to the Pointers and Polaris:

> I know the names, and somewhat more of all the constellations in my horizon; yet I have seen a prating mariner, that could only name the Pointers and the North Star, out-talk me, and conceit himself a whole sphere above me.

Polaris is a white or yellowish-white star of the sirian type, and is accompanied by a faint, but not close, ninth-magnitude companion, which is of a dull blue colour, and is sometimes used as a test for small telescopes. The primary star was found in 1899 to be a spectroscopic binary. Polaris is thus a *triple* star worthy of remark, and the three bodies of which it is composed revolve, under the influence of their mutual attraction, about each other. It is sixty-nine and a half light years distant, and has a proper or cross motion of two and a half miles a second. In the northern hemisphere it is frequently used by both astronomers and mariners for determining latitude; its height in the sky denoting approximately the latitude of the observer. Until the mariner's compass came into use, it was the universal guide for wanderers both by land and sea.

Bryant, in his beautiful *Hymn to the North Star*, thus refers to it:

> on thy unaltering blaze
> The half-wrecked mariner, his compass lost,
> Fixes his steady gaze,
> And steers, undoubting, to the friendly coast;
> And they who stray in perilous wastes by night,
> Are glad when thou dost shine to guide their footsteps
> right.

The second bright star is Kochab or Beta Ursæ Minoris, in the outer side of the bowl of the little dipper, or the left shoulder of the bear. It is a reddish-coloured second-magnitude star, of the solar type, about as bright as Polaris. It is situated fifteen degrees from the pole, and is about twenty-five degrees distant from Alcaid, and twenty-four degrees from Dubhe. Its nearest neighbour, about three and a half degrees distant, is a wide double, situated at the junction of the bottom of the bowl with the outer side, known as Gamma, a star of the third magnitude. Kochab and Gamma are frequently alluded to as the "Wardens" or "Guards" of the Pole.

Shakespeare, in *Othello*, Act II, Scene I, thus refers to them:

> The wind-shak'd surge, with high and monstrous mane,
> Seems to cast water on the burning Bear,
> And quench the guards of th' ever-fixed pole.

The star Zeta, at the root of the tail or at the junction of the handle with the bowl, is of the fourth magnitude, and the star Eta, at the back part of the bottom of the bowl, opposite Gamma, is of the fifth. The four stars in the bowl, namely, Beta, Gamma, Zeta, and Eta, it will be noticed, are respectively of the second, third, fourth, and fifth magnitudes, and hence are often used in comparing stellar magnitudes. The two stars in the curved-up handle, between Polaris and Zeta, are Delta, a greenish-tinged, fourth-magnitude star, and a faint star known as Epsilon.

Leo
(The Lion)

High up, near the zenith is the constellation Leo, one of the most beautiful and striking constellations

adorning the night-sky of spring. It is about the size of the Big Dipper, and is readily recognised by six of its principal stars which form the upright figure of a sickle, with its handle downward, and its blade turned toward the west. It is easily found when the position of the Greater Bear, which lies parallel to it, is known:

> Neath her hind feet as rushing on his prey,
> The lordly Lion greets the God of day.
>
> ARATUS.

Leo is the fifth sign in order of the zodiac, and the sixth and most famous of the zodiacal constellations. It contains over a hundred stars visible to the unaided eye, as well as a large number of interesting telescopic objects, and is bounded generally by the constellations Leo Minor, Cancer, and Virgo. It is represented as a crouching lion facing westward, the stars of the sickle, known as the "Sickle of Leo," forming the forepart of the animal, the hinderpart being outlined by three bright stars which form a triangle. The fore-paws are drawn up to the breast, and are represented by two faint stars, Psi and Omicron.

In the Middle Ages, Leo was called one of "Daniel's Lions," and by astrologers was known as the "House of Lions." As recorded in Genesis xlix., 9, the lion was the symbol of the tribe of Judah, and was Judah's natal sign.

According to Greek fable, it is connected with the story of the labours of Hercules, and is represented as the gigantic Lion—originally from the moon—which infested the Nemæan forests. It was strangled by Hercules, after his massy club and his arrows had proved unavailing, and was placed by Jupiter among the stars in commemoration of the exploit of his son.

The principal star in the constellation is Regulus, or Alpha Leonis, the "little king," a brilliant white star of the sirian type and of the first magnitude. It is situated at the lower end of the handle of the sickle or "reaping-hook," the other stars, of which, successively, are, Eta, Gamma, Zeta, Mu, and Epsilon. It sparkles near the heart of Leo, and is sometimes called "Cor Leonis" or the "Lion's Heart." It is about half a degree north of the ecliptic, and has a faint eighth-magnitude companion, which, as seen through a powerful field-glass, is of a deep blue colour. It is about ninety-nine light years distant, and has a proper or cross motion of twenty-two miles a second.

Regulus has been a famous star in all ages, and is one of the so-called "Lunar Stars," much used in navigation. It is of great repute among astrologers, and has always been looked upon as a fortunate star. It was the leader of the four celebrated "Royal Stars," or "Four Guardians of Heaven," and along with Aldebaran, Antares, and Fomalhaut, the other royal stars of the ancient Persian monarchy, watched over the four great districts of the heavens. It is visible for about eight months in the year, and comes to the meridian at 9 P.M. on April 6th.

The sun travels through Leo from August 7th to September 14th, and passes close to Regulus about August 20th, while the moon passes near the latter every month, and at times occults it. The constellation is best seen from January to June.

Denebola or Beta, another interesting star in Leo, is the eastmost star in the small triangle, and marks the tuft at the end of the lion's tail. It is a bluish second-magnitude star of the sirian type, almost as bright as Regulus, and is situated about twenty-five

degrees east of the latter, and five degrees north of the faint stars that form the head of Virgo. It is over twenty-five light years distant, and has a proper or cross motion of about eleven and a half miles a second. In its immediate vicinity are six small stars called the "Companions of Denebola," one of which is of the sixth magnitude and one of the eighth. It is five degrees west of the equinoctial colure, and comes to the meridian at 9 P.M. on May 3d.

In astrology it was regarded as unlucky, portending misfortune and disgrace to all born under its influence.

Denebola and Zosma form with Theta, a conspicuous triangle, and with Regulus and Gamma a large trapezium. Along with Arcturus in Boötes, Cor Caroli in Canes Venatici, and Spica in Virgo, it forms a great rhombus, the so-called "Diamond of Virgo," a striking figure almost fifty degrees long.

The bright star in the lion's shoulder and the lowest star in the blade of the sickle, is Algieba or Gamma, the second star above Regulus, and one of the most attractive stars in the northern heavens. It is a binary, or physical double, with a period, according to Doberck, of about four hundred and three years. The larger star is of a bright orange colour, and of the second magnitude, while the companion star is of a greenish-yellow hue, and of about the fourth magnitude. It is a star of the solar type, and is optically double even with an opera-glass. The radiant point of the famous Leonid meteors is within the curve of the blade of the sickle, near Gamma.

Zosma or Delta, a coarsely triple star of the sirian type, lies on the lion's back, near the tail. It is of a pale yellow colour, and of the third magnitude. Five degrees directly south of it is Theta, a third-magnitude

star situated in the thigh of the lion. South of Zosma and Theta, and almost in a straight line with them, are a few small stars which mark one of the hind legs. Seven degrees south-west of Denebola, and in the lion's flank, is a beautiful binary star, Iota. The larger star of the pair is of a lemon-yellow colour, and of the fourth magnitude, while the companion star is of the eighth magnitude, and of a light blue shade.

Five degrees north of Regulus is a fourth-magnitude star Eta, which forms with it the handle of the sickle. The third-magnitude star in the mane of the neck, and in the curve of the sickle, next to Gamma, is Zeta. It has three small companion stars, visible with a good opera-glass. Epsilon, a third-magnitude star in the cheek of the lion, has two seventh-magnitude companions, forming with it a beautiful little triangle. A little west of Epsilon, is Lambda, a fourth-magnitude star situated in the lion's open jaws.

The very interesting variable star, lettered R, in the right foreleg of Leo, is remarkable for its blood-red appearance, and has a period of about three hundred and twelve days. When at its maximum of radiance its light is that of a fifth-magnitude star, its minimum being reached at about the tenth magnitude. It will be at its maximum about November 21, 1914.

Leo Minor

(The Lesser Lion)

Leo Minor, the Lesser Lion, is a small constellation formed by Hevelius, in the latter part of the seventeenth century, out of the unformed stars scattered between Leo on the south and Ursa Major on the north. It contains no stars greater than the fourth magnitude, and to the Arabians was known as the Gazelle.

Hydra
(The Water-Serpent)

Hydra, sometimes called the Water-Snake, or the Water-Serpent, is a great sinuous constellation, winding eastward and southward below Leo, Crater, Corvus, and Virgo, as far as Libra. It is over one hundred degrees in length, stretching across nearly one-third the circumference of the heavens. The head of the sparkling reptile is under the Beehive cluster in Cancer, just north of the celestial equator, and its tail ends near the bright star Gamma in the uplifted claw of Scorpio.

> The Water-Serpent's gleaming bend.
>
> ARATUS.

In Greek mythology, Hydra was the dreadful monster which infested the marshes of Lerna, and to destroy which was the second labour of Hercules. It is related that the snake had a hundred heads, and that as soon as one was cut off, two immediately grew in its place, unless the wound was seared with a hot iron. Hercules, assisted by his faithful nephew Iolaus, who applied a hot iron to the stumps as fast as the head was clubbed off, easily effected its destruction, burying the centre head, which was said to be immortal, under a rock.

The head of Hydra faces westward and may be distinguished by five stars, which form a rhomboidal figure, two of the stars, namely, Zeta and Epsilon, being of the third magnitude, and Delta of the fourth. Epsilon is a remarkably fine double, for a three-inch telescope; one component being yellow and of the third magnitude, the other blue and of the eighth magnitude. When Hydra's head is on the meridian,

its other extremity, marked by two fifth-magnitude stars, is many degrees below the eastern horizon.

The principal star in the constellation is Alphard or Alpha. It is situated in the heart of the serpent, and is known sometimes as Cor Hydræ. It is a second-magnitude star of an orange-yellow colour and twinkles sluggishly. It received its Arabic name Alphard, meaning the "Solitary One," from its occupying a district in which there are no other bright stars. Its position in the heavens is easily detected, first by its isolated position, and secondly by an imaginary line drawn southward through Gamma Leonis and Regulus, to a point about twenty-five degrees distant from the latter. Besides, Castor and Pollux nearly point south to it. It comes to the meridian at 9 P.M. on March 26th.

The fifty-odd remaining stars in the vast folds of this great wriggling serpent, range from the third to the fifth magnitude and under, many of them being arranged in striking pairs, but otherwise unimportant.

Over in the south-east, resting on the back of Hydra, may be seen the quadrilateral figure of the constellation Corvus, and about fifteen degrees west of it, the overturned cup of the constellation Crater, while low down in the south-west, above Argo Navis, lies the unimportant southern constellation Antlia, the Air-Pump.

Corvus
(The Crow)

Corvus, the Crow or "Fig Bird," is a small constellation containing about ten stars visible to the unassisted eye. It can be readily recognised by four bright stars, which form an irregular quadrilateral, in a section

not very rich in large stars. Epsilon, the faintest of the four, the one situated in the neck of the crow, and in the lower right-hand corner of the figure, is of the third magnitude. Gienah, or Gamma, in the west wing of the crow, and in the upper right-hand corner of the figure, is now the brightest star in the constellation. It is of the second magnitude, and lies only one degree east of the equinoctial colure.

Beta, about as bright as Gienah, is on the foot of the crow, and in the lower left-hand corner of the figure, but, like Epsilon, has no specific name. Algorab, or Delta, the star in the east wing of the crow, and in the upper left-hand corner of the figure, is a beautiful double star of the second magnitude. The lowest star, Al Chiba, or Alpha, in the beak of the crow—which is depicted as pecking at Hydra—and once the leader of the constellation, is now only of the fourth magnitude.

According to Greek fable, the crow was placed among the stars by Apollo, as a reward for detective services. Having become jealous of Coronis, the beautiful daughter of Phlegyas, and mother of Æsculapius, Apollo, it is related, sent a crow to watch her. The intimacy of Coronis with Ischys, the Thessalian, as reported by the crow, so enraged Apollo, that

> the colour left his look,
> The wreath his head, the harp his hand forsook:
> The silver bow and feathered shafts he took,
> And lodged an arrow in the tender breast,
> That had so often to his own been prest.

Another legend, mentioned by Allen, relates that the crow, being sent by Apollo with a cup to bring some water for a sacrifice to Jupiter, loitered at a fig-tree till the fruit became ripe, and then returned to the god

with a water-snake in his claws, and a lie on his tongue, alleging the snake to have been the cause of his delay. In punishment for his dilatoriness and untruthfulness he was forever fixed in the sky with the Cup and the Snake, the latter being charged never to allow him to drink.

The crow, it is also said, was once of the purest white, but was changed, as a punishment for tale-bearing, to its present sable hue:

The raven once in snowy plumes was drest,
White as the whitest dove's unsullied breast,
His tongue, his prating tongue, had changed him quite,
To sooty blackness from the purest white.

Corvus comes to the meridian about 9 P.M. on May 10th.

Crater
(The Cup)

Like Corvus, Crater, the Cup, or the "Mixing Bowl," rests on the back of the great water-snake, Hydra. It is marked by seven stars immediately west of Corvus and south of Virgo, which form a somewhat striking bowl-shaped figure, in an inclined position, with the open part towards the east. It is a rather inconspicuous constellation, one of its stars, Delta, being of the third magnitude, Alkes and three others of the fourth, and two of the fifth.

Alkes, or Alpha, an orange-tinted star, formerly the brightest star in the constellation, but now much fainter than Delta, is situated in the bottom of the cup, and is common to both Hydra and Crater.

The Greeks seem to have looked upon Crater as the

"Goblet of Apollo," but according to Manilius it belonged to Bacchus:

> Next flies the Crow, and next the generous Bowl
> Of Bacchus flows, and cheers the thirsty pole.

Then, too, it has been differently known as the cup of Hercules, the cup of Achilles, and the cup of Medea; while later it has been identified with the cup that was found in Benjamin's sack, with the wine-cup of Noah, and even with a vial of wrath of the Revelation. Another legend connects it with the Soma cup of prehistoric India.

Allen states that there is an ancient vase in the Warwick collection on which are inscribed the following lines:

> Wise ancients knew when Crater rose in sight,
> Nile's fertile deluge had attained its height.

Crater's stars lie directly south of the hinder-feet of Leo, and come to the meridian at 9 P.M. on April 26th.

Argo Navis
(The Ship Argo)

Lying largely in the Milky Way, south of Hydra and Monoceros, and south-east of Canis Major, is the great constellation Argo Navis, the ship Argo, the most important part of which, for observation, is unfortunately too far south, as only a few stars in the stern of the ship are visible in this latitude. According to Greek fable it represents the famous ship built by Argo about 936 B.C., in which Jason and his fifty-four notable companions went to Colchis in search of the Golden Fleece. It was the first long vessel ever built, and is believed by some to be no other than the Ark of Noah.

Wordsworth thus refers to this constellation:

> When the first Ship sailed for the Golden Fleece—
> *Argo*, exalted for that daring feat
> To fix in heaven her shape distinct with stars.

And Aratus wrote of its position:

> Against the tail of the Great Dog is dragged
> Sternward the *Argo*.

The leading star of the constellation is a star of immense magnitude, called Canopus, after one of its pilots. It is situated in the keel of the ship, and is a bluish-white star of the sirian type. It is second only to Sirius in brilliancy, having a magnitude of −0.9. It can be seen from the Gulf States, but is not visible in this latitude. It is at least three hundred and twenty-five light years distant, has a proper or cross motion of eight and a half miles a second, and is receding from the solar system at the rate of over twelve miles a second. The notable second-magnitude star, Gamma, is said to be the only really bright star yielding the peculiar Wolf-Rayet type of spectrum—that is, a spectrum characterised by bright instead of dark lines, and also showing dark bands, the bright lines signifying that the atmospheric vapours producing them are at a higher temperature than the body of the star. The so-called Wolf-Rayet stars, it may be stated, are few in number, probably not over one hundred, and are all found in or very near the Milky Way, or in the Magellanic Clouds.

The constellation Argo contains a wonderful, irregularly variable star named Eta, which is surrounded by the great "Key-hole Nebula in Argus," a *variable*

nebula situated in one of the most brilliant portions of the Milky Way.

Over in the west the magnificent Orion, the interesting Taurus with its celebrated clusters the Hyades and Pleiades, the bright Twins, the brilliant Dog Stars, and the skilful Charioteer, are now declining rapidly toward the horizon, and will be described later, being more favourably situated in the chart of the winter night sky. The winter branch of the Milky Way, too, is swinging closer each night to the western horizon, while the northern end of the summer branch is just appearing in the north-east. Besides, what may be of more than passing interest to the observer, is a rather barren stretch of sky, separating the winter stars from the stars of spring, the "pointers" in Ursa Major and the stars in the triangle of Leo being the only bright stars in the great belt extending from the celestial pole to the southern limits of vision.

Of the on-coming constellations, the great Harvest constellation, Virgo, with its beautiful flushed-white star Spica, to the east, the large Boötes, with its brilliant orange-tinted Arcturus, in the north-east, and the constellation Lyra, the Lyre, with its blazing blue star Vega, to the north, are by far the most conspicuous.

Virgo
(The Virgin)

Virgo, the Virgin, the sixth sign and seventh constellation of the zodiac, lies close to the ecliptic, about half north and half south of the equator, and is bounded on the east by Libra, on the west by Leo, on the north by Boötes and Coma Berenices, and on the south by Corvus, Crater, and Hydra. It is a very old and noble

constellation of great dimensions and replete with astronomical interest. The sun occupies it for forty-five days, passing through it from September 14th to October 29th. All told, it contains one hundred stars visible to the naked eye, including one of the first magnitude, six of the third, and a number of the fourth, fifth, and sixth.

The principal stars admit of being linked up so as to form the outline of the flowing robe of a virgin. In most representations of Virgo, she appears as a beautiful maiden with folded wings springing from her shoulders, holding in her left hand a spear of wheat or an ear of corn, defined in the heavens by the position of the fascinating star Spica.

According to Hesiod, Virgo was Astræa, the daughter of Jupiter and Themis, and the goddess of justice. In the Golden Age, when the gods dwelt upon the earth, Astræa ruled the world, and was especially reverenced by men for her pure life and kindly deeds. But becoming offended at the wickedness and impiety of mankind during the Brazen and Iron Ages of the world, she returned to heaven. The last of the immortals to leave the earth, she

> Winged her flight to heaven; and fixed
> Her station in that region
> Where still by night is seen
> The Virgin goddess near to bright Boötes.
>
> ARATUS.

In Egyptian mythology, Virgo was associated with Isis, and it was said that as she fled to escape the dreadful giant Typhon, she dropped one of the three ripened ears of corn she held in her hand, which became scattered over the heavens and formed the Milky Way.

Another, a Greek fable, identified Virgo with Erigone, the daughter of Icarius, an Athenian, who was murdered by some shepherds whom he had intoxicated with wine. Directed by her faithful dog Mæra to the place where her father was slain, overcome with grief, she hung herself.

> Thus once in Marathon's impervious wood,
> Erigone beside her father stood,
> When hastening to discharge her pious vows,
> She loos'd the knot and cull'd the strongest boughs.
>
> STATIUS.

Virgo has also been associated with the Virgin Mary, and with Ruth gleaning in the fields of Boaz.

According to the late Andrew Lang, the old custom, still seen in some parts of England and Scotland, of escorting with music from the field, the "Kern-baby," made up of the last gleanings of the harvest, was derived from the myths relating to Virgo.

Astrologically, Virgo was a feminine sign, and was looked upon as generally unfortunate.

The most noted star in the constellation is the beautiful, white, first-magnitude star Spica, or Alpha Virginis, glistening in the spear of wheat or the ear of corn which the virgin holds in her left hand. It rises a very little south of the exact eastern point on the horizon, and may be known by its solitary splendour, there being no star at all approaching it in brightness within thirty degrees of it. It can be found by extending an imaginary line from the end of the handle of The Dipper through Arcturus, to about an equal distance beyond it. And again, an imaginary line drawn from Polaris through Mizar, the middle star in the handle of the

big dipper, will, if extended about sixty-five degrees, pass through Spica.

Spica belongs to the sirian type of suns, being young in the order of evolution, and is receding from the solar system at the rate of over four thousand miles an hour. Its actual magnitude is very great, and it exceeds the sun probably hundreds of times in intrinsic brightness. According to spectroscopic and also to more recent spectro-photographic investigations, it is a spectroscopic binary, its obscure companion star being of the tenth magnitude and bluish in colour. The two revolving bodies are said to complete a revolution in the remarkably short period of four days. Spica takes five hours and twenty-five minutes to reach the meridian, when it is somewhat less than half-way up from the southern horizon. It lies within the moon's path, and is one of the stars from which the moon's distance is taken for determining the longitude at sea. It culminates at 9 P.M. on May 27th.

The star Porrima, or Gamma, a third-magnitude star situated on the girdle near the left side, about ten degrees north of Spica, was one of the first binaries to be discovered. It is an interesting double star, and a fine object for a small telescope. The two components are about equal in magnitude, and are of a pale yellow colour. They have a period of revolution around a common centre of gravity, estimated at about one hundred and eighty years. Gamma is fifty-six light years distant, has a proper or cross motion of about twenty-eight miles a second, and is approaching the solar system at the rate of thirteen miles a second. It comes to the meridian at 9 P.M. on May 17th.

Epsilon, called also "Vindemiatrix," signifying "grape-gatherer," is a bright yellow star of the third

magnitude, in the right arm, or northern wing, about midway between Spica and the delicate cluster of stars which forms the "Maiden's Hair," or Coma Berenices. It was known to the Arabs as the "Forerunner of the Vintage," because its heliacal rising was the herald of the vintage time. It has a minute distant companion star, of a deep red colour.

Zavijava, or Beta, a third-magnitude star below Denebola, marks the top of the left wing, while Zaniah, or Eta, also of the third magnitude, is in the heart, about five degrees west of Gamma. The autumnal equinox, or the place where the sun crosses the celestial equator on his southerly journey about the 23d of September, is situated nearly between the stars Eta and Beta. The stars Delta and Zeta of the third magnitude, and Theta, a double star of the fourth, along with a number of smaller stars, are dotted over the maiden's flowing robe. Six stars of from the fourth to the sixth magnitude are in the head of the Virgin, and three, namely, Lambda, Iota, and Pi, are in the feet. The stars Zeta and Gamma form with Spica a handsome triangle.

The space marked out by the set of five stars, Beta, Eta, Gamma, Delta, and Epsilon, has been called the "Field of the Nebulæ," on account of the great number of nebulæ found in this region. To the Arabs, the cup-shaped figure formed by these stars was known as "The Retreat of the Howling Dogs" (Canes Venatici).

Cancer
(The Crab)

Above the head of Hydra, and between Leo and Gemini, lies Cancer, the Crab, the smallest and least

conspicuous of all the zodiacal constellations. It is a very ancient constellation, and is important mainly from its position in the zodiac.

Dante, alluding to its faintness and high position in the heavens, wrote in the *Paradiso* (Longfellow's tr.):

> Thereafterward, a light among them brightened,
> So that, if Cancer one such crystal had,
> Winter would have a month of one sole day.

Cancer's principal stars, none of which are brighter than the fourth magnitude, form an inverted Y. The total length of the ⅄ is about twenty degrees. A pair of the stars, Gamma and Delta, have been known from time immemorial as the "twin Asses," or the "Aselli." Gamma, or the Asellus Borealis, and Delta, or the Asellus Australis, stand respectively north and south of their Manger, a famous naked-eye cluster of small stars called "Præsepe." Delta, the southern Asellus, a delicate double star, is situated in the line of the ecliptic.

The historic cluster Præsepe, the "Beehive," or the celestial weather-glass, in the breast of the sprawling crab, about ten degrees south of Pollux, is the most noticeable and interesting feature of Cancer. It lies nearly between the "Aselli," a little to the west, and on very clear nights, when the moon is absent, is visible to the naked eye as a little faint cloud, which a large opera-glass or a small telescope will easily resolve into an aggregation of small stars. It is of about the same size as the Pleiades, and is composed of three hundred and sixty-three stars. It has often been mistaken by amateur observers for a comet.

Like a little mist,
Far north in Cancer's territory, it floats.
Its confines are two faintly glimmering stars;
These are two Asses that a Manger parts.

ARATUS.

In ancient times Præsepe, or the Manger, was regarded in the light somewhat of a weather-guide.

Pliny thus refers to it: "If Præsepe is not visible in a clear sky, it is a presage of a violent storm."

And Aratus in *Prognostica* wrote:

A murky Manger with both stars
Shining unaltered, is a sign of rain.

According to Macrobius, the name Cancer was selected by the Chaldeans to represent this constellation, because the crab, being an animal that walks backward or obliquely, well typified the sun's apparent retrograde movement when it was in this part of the zodiac.

I was born, sir, when the Crab was ascending,
And my affairs go backward.

CONGREVE.

According to Greek legend, Cancer represents the gigantic sea-crab that came to the assistance of the water-snake, and seized the foot of Hercules, as he was fighting with Hydra in the Lernæan marshes. The hero crushed the reptile under his heel and slew it, whereupon Juno, in gratitude for the offered service, importuned Jupiter to place the crab among the constellations.

Another legend relates that Bacchus, while on the way to the temple of Jove, came to a great marsh, over

which he was carried by an ass, one of two near-by at the time. In return for this gracious service, he transformed both creatures into stars, and placed them in the heavens, where they have remained as the "twin Asses" to this day.

In astrology Cancer was known as a dark sign, and was most unfavourably regarded. The Aselli were portents of violent death to such as came under their influence, while Præsepe, or the Beehive, like all clusters, threatened mischief and blindness. To the Chaldeans, Cancer or rather Præsepe was known as the "Gate of Men," the region of the stars through which, when human beings were born, the souls that were to animate their bodies descended from heaven to earth.

The star Acubens, or Alpha Cancri, is a double star of the fourth magnitude situated in the south-eastern claw, with two very small stars near it. It comes to the meridian at 9 P.M. on March 18th. Beta, also a fourth-magnitude star, is in the south-western claw, midway between Acubens and the bright star Procyon in the Lesser Dog. Zeta Cancri is a fine quadruple star near the hind claws of the crab, and is one of the most famous of stellar systems. Seeliger of Munich, who has given this system much study, believes that three bright stars in it—of the fifth-and-a-half, sixth, and sixth-and-a-half magnitudes respectively—revolve round a dark body, apparently the most massive of the four. The star Iota is a pretty double, formed by a yellow star of the fourth magnitude and a companion of the sixth magnitude.

The sun is travelling through the constellation from July 18th to August 7th.

Coma Berenices
(Berenice's Hair)

Coma Berenices, "Chioma di Berenice," or Berenice's Hair, is a beautiful little constellation lying north-east of Denebola, midway between it and Cor Caroli. It is one of the most fairy-like objects in the sky, and contains about ninety stars, only three of which are as bright as the fourth magnitude. It is situated at the northern pole of the Milky Way, and contains many small nebulæ, also a number of double stars with lilac-coloured companions. The most crowded part, a delicate, irregular cluster of very faint stars, visible to the naked eye as a glimmering spot, is a pretty sight in an opera-glass.

With marked appropriateness does *The Poet at the Breakfast Table* allude to

> The spangled stream of Berenice's hair.

Bryant, too, in *The Constellations*, notices

> The streaming *tresses* of the Egyptian queen.

In the mythological history of Coma Berenices, it is related that when Ptolemy Soter, or Euergetes, one of the kings of Egypt, started on a dangerous expedition against the Assyrians, Queen Berenice vowed to consecrate her fine head of hair to the temple of Venus, in case he returned safely. On his successful return she fulfilled her vow, and Jupiter placed the shining "tresses" among the stars.

According to Eratosthenes, this constellation has also been identified with the hair of Ariadne.

Dr. Seiss claimed that it was vertically overhead at

Jerusalem on the 25th of December at the time of Christ's birth, and associated it with the Star of the Magi.

Canes Venatici
(The Hunting Dogs)

Canes Venatici, or the Hunting Dogs, is an interesting modern constellation formed by Hevelius in the 17th century, out of the unformed stars scattered between Coma Berenices, Boötes, and the Greater Bear. Its stars, one of which is of about the second magnitude, one of the fourth, and a number of the fifth, are supposed to represent a pair of hunting dogs or hounds, which, held in leash by Boötes, are pursuing the great Bear continually round the pole.

> Boötes hath unleash'd his fiery hounds.
>
> OWEN MEREDITH.

The northern dog is named Asterion, and the southern one, Chara. In the neck of the latter is situated the beautiful Cor Caroli, or "Charles's Heart," a white star of about the second magnitude. It is the leading star of the constellation, and was named Cor Caroli by Halley, the Astronomer Royal, at the suggestion of Sir Charles Scarborough, the Court physician, in memory of Charles I.

Cor Caroli is a wide double star, having a sixth-magnitude companion of a pale lilac colour, and is an easy object for very small instruments. It can be readily found by drawing an imaginary line from Polaris through Alioth in Ursa Major, which will lead directly to it. It forms an equilateral triangle with the stars Phad and Alcaid in Ursa Major, and is also one of the four stars forming the "Diamond of Virgo." It comes to the meridian at 9 P.M. on May 20th.

Mount Wilson Solar Observatory

PLATE IV. Owl Nebula in Ursa Major

Yerkes Observatory

PLATE V. Spiral Nebula in Canes Venatici
(Showing detached mass)

In the head of the northern dog Asterion, about three degrees distant from Alcaid, or Eta Ursæ Majoris, can be seen the famous Whirlpool Nebula (Plate V.). It is invisible to the naked eye, but shows itself in a small telescope as a bright nebulous cloud, the material of which, as it shrinks under its own gravitation, is becoming arranged in a spiral form. As is the case of nearly all spiral nebulæ, it will continue to contract and grow hotter and be transformed, it is believed, into a central sun with a system of worlds moving around it in a nearly round orbit. The majority of the nebulæ of the sky, it is known, have a spiral form, and it is now generally believed that a great part of the stars are the centres of true solar systems. Out of these infinite varieties of worlds, may there not be many planetary bodies which have already reached the stage of habitability, and be peopled by diverse and unimaginable forms of life!

The plurality of inhabited worlds is thus beautifully alluded to in Alexander Pope's *Universal Prayer*—the *Te Deum laudamus* of that broad Christian church which embraces God-loved humanity:

Father of all! in every age,
In every clime adored,
By saint, by savage, and by sage,
Jehovah, Jove, or Lord.

Yet not to earth's contracted span
Thy goodness let me bound,
Or think Thee, Lord, alone of man,
When *thousand worlds* are round.

If I am right, Thy grace impart,
Still in the right to stay;
If I am wrong, oh! teach my heart
To find that better way.

Boötes
(The Bear-driver)

Lying south of the Greater Bear and between the Heart of Charles on the west, the Northern Crown on the east, and the Virgin on the south, is a fine, rich, straggling constellation, nearly fifty degrees in length, called Boötes,

> whose order'd beams
> Present a figure driving on his teams,
> Below his girdle, near his knees, he bears
> The bright Arcturus, fairest of the stars.
>
> MANILIUS.

The name Boötes is used by Homer, and means a ploughman, or according to some authorities an ox-driver, and is not infrequently translated the "Herdsman." By the Greeks, Boötes was referred to as the "Bear-keeper," or "Bear-driver," because he seems to be driving the great Bear before him, in its ceaseless journey around the pole.

> Boötes only seemed to roll
> His Arctic charge around the pole.
>
> BYRON.

In his *Sartor Resartus*, Chapter III., *Reminiscences*, Thomas Carlyle mentions him, when he alludes to Herr Teufelsdrockh as having said when he returned from the coffee-house at midnight: "It is true sublimity to be here. These fringes of lamplight, struggling up through the smoke and thousand-fold exhalation, some fathoms into the ancient region of Night, what thinks Boötes of them, as he leads his Hunting Dogs over the zenith in their leash of sidereal fire?"

The constellation is usually represented by the figure of a tall man in a running attitude, grasping a spear, club, or pastoral staff, in his right hand; and holding in his uplifted left hand the leash of his two hunting dogs, Asterion and Chara, which seem to be barking at the great Bear. It is visible in this latitude from March to November, and contains one star seven-tenths of a magnitude above the first rank, one star of nearly the second magnitude, six of the third, and a number of the fourth, fifth, and sixth. It may be easily distinguished by the position and splendour of its principal star, the celebrated golden-hued Arcturus, which may be found by following the curve of the handle of The Dipper, prolonged about thirty degrees.

On account of the peculiar shape of this pentagonal constellation, it rises horizontally and very rapidly, a little north of east, all of its stars emerging from below the horizon at about the same time. But it sets in so nearly the upright position, that it requires more than eight hours to slowly sink below the north-west horizon.

Aratus, alluding to its slow setting, describes Boötes as:

> One who
> When tired of the day
> At even lingers more than half the night.

Mythologically, accounts of Boötes vary considerably. According to one Greek fable, having been robbed of all his goods by his brother, Boötes, after many hardships and wanderings, invented a plough, which was drawn by two oxen. With this he tilled the land and made a living thereby. So highly pleased was his mother, Callisto, at his cleverness, that, desiring to preserve the memory of his invention, and at the same time

reward him for so industriously working the land, she induced Zeus to place him in the sky together with the plough. In his system of gospel mythology Seiss identifies Boötes with the "Great Shepherd and Harvester of Souls."

The most striking object in the constellation is Arcturus, or Alpha Boötis. It is one of the most beautiful stars in the heavens, and has been the admiration of all ages.

In his beautiful poem to *Arcturus*, Whitman writes:

> Star of resplendent front; thy glorious eye
> Shines on me still from out yon clouded sky.

Elgie tersely alludes to it as the harbinger of spring and the apotheosis of summer. It ranks with Canopus as one of the largest stars in the universe, its diameter being estimated at several million miles, and its mass at several hundred times that of the sun. So distant is it that its light takes forty-three and a half light years to reach the earth. Then, too, it has the most rapid motion of any of the brighter stars, and has been rightly called a giant "runaway star." While it is approaching the earth at the rate of only three miles a second, it is moving along the face of the sky at a speed of over eighty-nine miles a second. In the course of a century, by reason of this very rapid motion, it changes its place among the other stars, by a distance equal to one-eighth of the moon's apparent diameter.

It belongs to the solar type of suns, although its spectrum indicates that it is a little farther along than the sun in its development from a gaseous to a solid body. It is probably surrounded, as Serviss states, with a blanket of absorbing metallic vapours, which

cuts off a large part of its radiant energy and gives it a ruddy hue.

It exceeds the sun in intrinsic brilliancy at least two hundred times, and could the latter be moved out into the depths of space as far as Arcturus, it would appear as faint as a tenth-magnitude, telescopic star, entirely invisible to the naked eye. It is two and a half times brighter than Aldebaran or Altair, and nearly four times brighter than Regulus, its principal rivals in the northern sky being Vega and Capella. It is said to give out more heat than Vega, and is believed by some to be the hottest star in the universe. The amount of heat, however, received from it has been proved to be no more than would come from a candle at a distance of five miles.

On October 5, 1858, the brightest part of the tail of Donati's great comet—then a magnificent spectacle in the northern sky—passed over Arcturus, without apparently dimming its lustre.

Twelve centuries ago, Arcturus was a guide to the husbandmen. Thus Hesiod, in the second book of his *Works and Days*, wrote:

> When in the rosy morn Arcturus shines,
> Then pluck the clusters from the parent vines:
> And when Arcturus leaves the main to rise
> A bright star shining in the evening skies,
> Then prune the vine.

Accordingly, if Hesiod is to be accredited as an authority on agriculture, vines should be pruned about the end of February or the beginning of March.

Arcturus has been called the "Watcher" or "Guardian" of the Bear, and to the Arabs was known as the "Keeper of Heaven." It is one of the few stars alluded

the great "Dragon of the North." It is usually represented by the figure of a long, sinuous serpent, curving from between the "pointers" and the pole, partly encircling the Lesser Bear, and finally reaching out its head, with gleaming eyes, toward the right foot of Hercules. It is a very ancient constellation, and is believed by many to be the crooked serpent of Job xxvi., 13:

> His hand hath formed the crooked serpent.

The north pole of the ecliptic is situated midway between Zeta and Delta, almost in the centre of the great loop formed by the dragon's coils, and close to the famous *planetary nebula* (N. G. C. 6543), which is supposed to be moving towards the solar system at the rate of forty miles a second.

> With vast convulsions Draco holds
> Th' ecliptic axis in his scaly folds,
> O'er half the skies his neck enormous rears,
> And with immense meanders parts the Bears.
>
> ERASMUS DARWIN.

In the first book of his didactic poem, the *Georgics*, Virgil, as rendered by Dryden, writes:

> Around our pole the spiry Dragon glides,
> And, like a wandering stream the Bears divides—
> The less and greater, who, by Fates' decree,
> Abhor to dive beneath the northern sea.

Altogether Draco contains over eighty stars, including one of about the second magnitude, nine of about the third, and a number of the fourth and fifth.

The head of the dragon lies just north of Iota Her-

culis (which is in the giant's left foot), and is marked by a conspicuous quadrilateral formed by the stars Eltanin or Gamma, Rastaban or Beta, Xi, and Nu. The bright stars Eltanin and Rastaban mark the "dragon's eyes," while Xi and Nu, along with Mu, a double fifth-magnitude star at the snout, make up the jaw. Several scattered groups and little triangles of stars outline the various coils of the body, while an irregular line of stars traces out the tail.

The leading star of the constellation, though not now its brightest star, is Thuban, or Alpha Draconis, situated in the fifth coil of the dragon near the tail, about half-way between Mizar in Ursa Major and the star Gamma in Ursa Minor, one of the Wardens of the Pole. It is of a pale yellow colour, and was formerly a second-magnitude star, but now below the third magnitude in brightness. Forty-odd centuries ago it was situated very near the pole of the heavens, and was then the north polar star. As mentioned in the previous chapter, it was the orientation star of the Great Pyramid of Cheops. It comes to the meridian at 9 P.M. on June 7th.

Eltanin, or Gamma, the right-hand upper star in the head of the dragon, is now the brightest star in the constellation. It is a beautiful orange-coloured star of nearly the second magnitude. It is situated less than two degrees west of the solstitial colure, and forms an equilateral triangle with Polaris and Alcaid. It is famous as being the star which led Bradley, in 1725, while attempting to verify Hooke's illusory parallax, to discover the laws of the aberration of light. It is the zenith star of Greenwich, and it has been supposed that Flamsteed, the first Astronomer Royal of Great Britain, sank a well at Greenwich Observatory for the

purpose of viewing it with the naked eye by daylight, as well as of measuring telescopically its distance from the true zenith at the moment of transit. It has been identified as the orientation star of Rameses' great temple at Karnak, and of that of Thot at Thebes—the City of the Dragon. It is about thirty and a half light years distant, and is approaching the solar system at the rate of nearly seventeen miles a second.

About four degrees to the left of Eltanin is Rastaban, or Beta, a yellowish star of the third magnitude in the left eye of Draco. It has a very distant companion of the tenth magnitude, and of a bluish colour. Xi, in the jaw, is also a third-magnitude star, and Nu is one of the fourth. Grumium, a third-magnitude star, is in the lower right-hand corner of the quadrilateral forming the head.

Omicron, a golden-yellow fourth-magnitude star, along with several stars of the fifth magnitude, forms the first coil. Delta, a third-magnitude star of a deep yellow colour, is situated in the second coil. Zeta, another third-magnitude star, is in the third coil, nearly in line with and midway between Kochab and Eltanin. Following these is the star Lambda, or Giansar, also of the third magnitude, at the end of the dragon's tail. It may be readily recognised lying between Polaris and the bowl of the Big Dipper, about eight degrees from Dubhe.

In Greek mythology, Draco is sometimes represented as the watchful dragon, Ladon, which guarded the golden apples in the famous garden of the Hesperides, at the foot of the hyperborean Atlas, and was slain by the redoubtable Hercules, who for his eleventh labour was ordered to procure some of them. Gæa, the earth-goddess, it is said, produced these apples—the symbol

of love and fruitfulness—as a wedding gift for Jupiter and Juno, and Juno rewarded the dragon for his faithful services by placing him among the stars.

Moore, in *Irish Melodies*, hints that Ladon may have been sleeping at his post when Hercules entered the Hesperian grove:

> So oft th' unamiable dragon hath slept,
> That the garden's imperfectly watched after all.

Draco was also identified with the dragon slain by the Thracian hero Cadmus, the teeth of which, sown on the advice of Minerva, produced, it is said, a most startling crop of armed and sanguinary men. Then, too, one of the old Greek legends asserts that when the Olympian gods waged war on the earth-born giants, the dragon was brought into the combat and opposed to Minerva. The intrepid goddess suddenly seized it in her hands, and hurled it, twisted as it was, up into the sky. By chance it became entangled in the axis of the heavens before it had time to uncoil, and there, forever fixed, it sleeps curled up among the stars.

CHAPTER III

THE NIGHT-SKY OF SUMMER

The epoch of the summer solstice, which occurs about the 21st of June, when the sun is at its farthest northern declination, marks the longest day of the northern hemisphere, and the first night-sky of summer. At about 9:30 P.M., the beautiful, but not very conspicuous, constellations of summer appear as represented in Chart II., and with its help they may be readily traced as they mount up and cross the sky,

> A silent night-watch o'er the world to keep.

The same chart represents the appearance of the great dome of the sky at about 11 P.M. at the beginning of June, about 10 P.M. the middle of June, about 9 P.M. the first week of July, and 8 P.M. about the middle of July.

The magnificent winter constellations have now about all disappeared in the west, while the last of the spring constellations are sinking rapidly towards the horizon. High up in the north-west is the Greater Bear, descending the starry slope head foremost, and directly in the north is the Lesser Bear postured acrobatically on the tip of his tail.

In the far north the yellow star Capella, the chief of the dauntless Charioteer, is seen scintillating palely,

CHART II–SUMMER NIGHT SKY

and just ready to set; while in the south-west are seen the two bright stars of the Balance, or golden Scales. Just west of the meridian, near the zenith, is the Y-shaped group of stars composing the straggling Bear-driver, and the delicate Northern Crown. Vertically beneath the Crown is the head of the Serpent, and on the east, almost overhead, is the great group of Hercules with its wonderful cluster. Beyond Hercules towards the north-east is the diamond-shaped head of the great shining Dragon.

Far down towards the southern horizon is the Scorpion with its leader the blazing red star Antares. In the Milky Way, east of the Scorpion, lies Sagittarius, the Archer, with the inverted little milk dipper and the bended bow. Above the Scorpion and the Archer are the intertwined constellations of Ophiuchus, the Serpent-bearer, and his Serpent.

Low in the north-east is Cassiopeia, the Lady in the Chair. And over in the eastern sky, half-way up to the zenith, is the Lyre, or heavenly Harp, with its bluish-white star Vega; while, buried in the Milky Way, the beautiful Northern Cross, extended on its side, shines out above it in the north-east. South-east of the Cross, near the eastern side of the Milky Way, are the three prominent stars in the neck of the flying or soaring Eagle, with the pretty little group of the Dolphin, popularly known as Job's Coffin, near-by. The summer branch of the Milky Way now shines as a majestic astral arch across the sky from the north-eastern to the south-western horizon, and its great bifurcation can be readily traced from Cygnus, the Swan, where it begins, past the Lyre, and through the flying or soaring Eagle, to the Archer and the Scorpion.

Libra
(The Scales)

Lying south of the equator, east of Virgo and west of Scorpio, is the small and inconspicuous asterism Libra, the Balance, or the Scales. It is the seventh sign and the eighth constellation of the zodiac, and is the only zodiacal sign that represents an inanimate object, and also the only one not of Euphratean origin. It crosses the sky from south-east to south-west during the summer months, and may be readily recognised by the rude square formed by its four principal stars.

Originally its stars represented the outstretched claws of the imaginary scorpion, and were, it is believed, separated from that venomous monster in the time of Julius Cæsar, and called Libra, the Balance. In classic days it marked the autumnal equinox, but owing to *precession* that position is now held by Virgo.

James Thomson, in the Autumn of his *Seasons*, writes:

> Libra weighs in equal scales the year.

In the time of Augustus Cæsar, it was regarded as the balance of Astræa, the goddess of justice, and by it the fate of mortals was supposed to be weighed. According to Greek legend it was placed in the zodiac to perpetuate the memory of Mochus, the reputed inventor of weights and measures. Cæsius thought that it represented the balances of the Book of Daniel in which Belshazzar had been weighed and found wanting.

Virgil in his flattering address to the Emperor Augustus, in the First *Georgic*, alludes to the glowing scorpion as contracting his claws for the special purpose of leaving for him a more than ample space in the sky.

And Milton in his *Paradise Lost*, Book IV., in the account of Gabriel's discovery of Satan in Paradise, and the threatened battle, thus refers to the Scales:

> The Eternal, to prevent such horrid fray,
> Hung forth in heaven his golden scales, yet seen
> Betwixt Astræa and the Scorpion sign,
> Wherein all things created first he weighed.

The ancient tillers of the soil, according to Virgil, regarded the sign Libra as indicating the proper time for sowing their winter grain. Thus Dryden, in his translation of the first book of the *Georgics*, writes:

> But when Astræa's Balance, hung on high
> Betwixt the nights and days, divides the sky,
> Then yoke your oxen, sow your winter grain,
> Till cold December comes with driving rain.

The sun occupies this zodiacal constellation from the 29th of October until the 21st of November.

In astrology Libra is a masculine sign, and fortunate. Its natives—those born from September 23d to October 23d—are said to be ruled by it.

Libra contains two stars of the second magnitude, two of the third, and a few of the fifth.

Alpha Libræ, or Zubenelgenubi, meaning the southern claw, is in the southern scale of the Balance. It is a yellowish-white star of the second magnitude and is widely double, having a fifth-magnitude companion of a light grey colour, easily seen with an opera-glass. It lies almost exactly on the ecliptic, and is situated midway between Spica and Antares. It culminates on June 17th at 9 P.M.

Beta Libræ, or Zubeneschemali, meaning the north-

ern claw, is in the northern scale of the Balance. It is situated about ten degrees north-east of Alpha, and is the brighter star of the two. It is an interesting variable, and has been called the "Emerald Star," as it is the only naked-eye green-coloured star in the sky. It is of the second magnitude and is widely double, having a companion of a light blue colour. It belongs to the sirian type of stars, and is said to be approaching the solar system at the rate of about six miles a second. Beta Libræ forms an equilateral triangle with Arcturus and Spica, and one also with Alpha Libræ and Mu Virginis. Due south of it lies the globular cluster 5 M., known to contain 85 short-period variables.

Delta, a star of the fifth magnitude, near the centre of the beam of the Balance, is a remarkable short-period variable of the Algol type. In five and a half hours it fades to the sixth magnitude, and after six and a half hours it regains its former brightness. It then remains stationary for about forty-four hours, after which it fades again. Its total period is stated as two days, seven hours, and fifty-one minutes.

Corona Borealis
(The Northern Crown)

Corona Borealis, or the Northern Crown, is a strikingly beautiful little constellation, sometimes called "Ariadne's Crown," situated just east of the northern part of Boötes, and directly north of the Serpent's head. It is confined in a very limited space, being only about fifteen degrees across, and is nearly in line between Vega and Arcturus. It is of great antiquity and is marked by seven twinkling stars, arranged in an

almost perfect semicircle, resembling very closely a crown of sparkling jewels. It is one of the few constellations which bear any similarity to the objects they are supposed to represent.

According to fable it commemorates the celebrated crown of seven stars presented by Bacchus to Ariadne, the daughter of Minos, son of Jupiter and second King of Crete, to console her for the desertion of the faithless Theseus. It is related that Theseus, son of Ægeus, King of Athens, went as one of the seven youths, whom the Athenians were obliged to send every year, with seven maidens, as a tribute to Crete, then a powerful maritime state, to be devoured by the ferocious Minotaurus, which was kept in the labyrinth at Cnosus.

The beautiful Ariadne became passionately devoted to Theseus, and provided him with a sword with which he slew the Minotaurus, and a clue of thread by means of which he found his way out of the labyrinth. The young prince Theseus in return promised to marry her, and she accordingly left Crete with him. But on their arrival at Naxos, an island in the Ægean Sea, celebrated for its wine, the ungrateful Theseus basely abandoned her. Here the god Bacchus is said to have found the disconsolate Ariadne, and made her his wife. After her death, as a memorial to her honour, the glorious crown of seven stars, which he gave her at the time of their marriage, was placed in the sky beneath the guarding club of Hercules.

> There, too, that Crown which Bacchus set on high,
> A brilliant monument of dead Ariadne.
>
> ARATUS.

Manilius, in the first book of his poem entitled *Astronomica*, thus refers to it:

if about to strike the heel of Ophiuchus, who appears to be trampling upon it. It is very irregular in shape, but resembles the object after which it is named more than do most constellations. It requires little play of the imagination to fancy the huge and baneful reptile trailing along the southern horizon, the stumps of its sundered claws reaching out towards Libra, and its long curved tail just dragging clear of the earth.

It is the most southerly of the zodiacal constellations, and can be seen crossing from south-east to south-west, from about the first of June until late in October. It is about twenty-five degrees in length, its eastern extremity being immersed in the Milky Way, and may be found by drawing downward for about sixty degrees a line at right angles to Altair and his two companions. Then, too, its brightest gem, Antares, is nearly south of Ras Algethi in the foot of Hercules, and almost as far beyond Spica as Spica is beyond Regulus.

In his beautiful fable of Phaëthon, Ovid, who lived in the time of our Saviour, thus refers to the constellation:

> There is a place above, where Scorpion bent,
> Its tail and arms surround a vast extent,
> In a wide circuit of the heavens he shines,
> And fills the place of two celestial signs.

The sun enters the sign Scorpio on the 23d of October, but does not reach the constellation before the 21st of November, which it occupies until the 16th of December.

Besides Antares, Scorpio contains two stars of the second magnitude, about nine of the third, and several of the fourth and fifth.

In mythology, one of the legends connects the Scorpion with the story of Orion, the mighty hunter. It

is said to be the famous reptile which sprang out of the earth at the command of Juno and bit the foot of Orion, causing his death. Scorpio and Orion are so placed in the heavens that just as the former rises in the eastern sky the latter dips below the western horizon. The two constellations never appear in the heavens together.

> When the Scorpion comes
> Orion flees to the utmost end of earth.
>
> ARATUS.

And yet the Scorpion itself was in danger, as Sackville, in his introduction to the *Mirror for Magistrates*, writes:

> Whiles Scorpio, dreading Sagittarius' dart
> Whose bow prest bent in flight the string had slipped,
> Down slid into the ocean flood apart.

Another fable connects the Scorpion with the story of Phaëthon as the cause of the disastrous runaway of the steeds of Phœbus Apollo, divine king of the heavens. Phaëthon was the son of Helios or "old Father Phœbus," by the Oceanid Clymene, the wife of Merops, King of the Ethiopians. It is related that "this roaring young blade" was presumptuous and ambitious enough to request "his doting old father" to allow him, for one day, to drive the chariot of the sun across the heavens.

> Nay, Phaëthon, don't
> I beg you won't.
>
> SAXE.

Induced by the entreaties of his son and of Clymene, Helios, however, finally yielded, and the horses were

harnessed. But Phaëthon, being an inexperienced driver, the horses, starting in Aries, soon got beyond control, and dashing off from their usual track, rushed headlong through the constellations (Plate VI.). As they approached the scorpion with its immense tail and horrid sting upraised ready to strike, Phaëthon, terror-stricken, dropped the reins. The horses, stung by the scorpion, took fright, and plunging wildly, hurled the chariot over the trackless wastes, so near the earth as almost to set it on fire. Thereupon, Jupiter struck the ambitious youth with a flash of lightning, and tumbled him headlong from his chariot down into the great sky-river Eridanus. His three sisters, the Heliades, who had harnessed up the horses to the chariot, bewailed the death of their brother so bitterly on the banks of the Eridanus, that the gods in compassion changed them into poplars, and their tears into amber. Ovid duly commemorated their grief in the following lines:

> All the long night their mournful watch they keep,
> And all the day stand round the tomb and weep.

In the Hebrew zodiac, Scorpio is allotted to Dan, because it is written, "Dan shall be a serpent by the way, an adder in the path" (Genesis xlix., 17).

Astrologically considered, Scorpio is the house and joy of Mars. Those born from October 23d to November 22d are said to be ruled by it. It is a feminine sign, and is regarded as unfortunate. The ancients supposed it to be emblematic of fevers and other diseases which prevail in the autumn.

In Dante's *Purgatorio* (Longfellow's tr.) it is referred to as:

PLATE VI. Phaëthon Driving the Chariot of the Sun

that cold animal
Which with its tail doth smite amain the nations.

The most noted star in the constellation is Antares or Alpha called also Cor Scorpionis or Le Cœur du Scorpion, the heart of the Scorpion. It is a nearly first-magnitude star of a fiery red colour situated in the heart of the venomous reptile. It owes its name to its being the reddest bright star in the sky, the rival of Mars, the ruddy planet, in brightness and colour (from the Greek *Anti*, like, and *Ares*, Mars). It lies south of the celestial equator in a long and curving row of bright stars which mark the body and reverting sting of the scorpion. It is pointed out by a line starting at Polaris, and running thence directly south, about half-way between Arcturus and Vega, for a distance of about 116 degrees. Along with Arcturus and Spica it makes up a magnificent right-angled triangle, Spica making the right angle. And again, it forms with Vega and Arcturus a great isosceles triangle, of which the latter star is the apex.

It rises in the south-east and is so far south of the equator that it requires only four hours and a quarter to reach the meridian, when it is only one-quarter of the way up from the horizon to the zenith, It appears above the horizon nearly an hour before Altair, an hour and a half after Deneb, and about two hours and a half after Vega. On the first day of June it rises just as the sun sets, and culminates at 9 P.M., on July 11th. It will be seen at its brightest in the latter part of June and during July.

Antares is a magnificent binary, having an emerald green companion star of the seventh and a half magnitude, which forms a strong contrast to the flaming red

of the larger star, and can be seen with a moderately small telescope. It has two small stars, Sigma and Tau, of about the third magnitude, which stand like guardians on either side. The fiery red colour of Antares indicates that it belongs to the type of suns that are far advanced in development, and in which, as Serviss states, the absorbing envelopes have become so dense that they are fast approaching extinction. And yet as the average duration of solar life is many million years, its ultimate extinction may not take place for untold ages. Some authorities claim that with all its waning, it sends out nine hundred times as much light as the sun. It is about 112 light years distant, has a proper or cross motion of 180 miles a minute, and is approaching the solar system at the rate of about 114 miles a minute.

Antares was one the four Royal stars of the ancient Persians, and the oldest of the Grecian temples were oriented to it.

North-west of Antares are two second-magnitude stars, Beta and Delta, which with Pi, a third-magnitude star south of them, form a nearly vertical curve, about seven degrees in length, which marks the front of the scorpion's head. The tail is formed by several third- and fourth-magnitude stars, which sweep in a magnificent U-shaped curve through the Milky Way, ending about seventeen degrees south-east of Antares, in a pair of bright stars which mark the reptile's uplifted sting. Beginning with Epsilon, the names of these stars are, Mu, Zeta, Eta, Theta, Iota, Kappa, Lambda, and Upsilon. The three stars, Kappa, Lambda, and Upsilon, in the extremity of the tail, form a small triangle. The twin stars Shaula or Lambda, and Lesuth or Upsilon, are situated in the reverted sting

of the scorpion, Shaula being the brighter of the two.

To the Polynesians the crooked line of stars from Mu to Upsilon, which form the tail, was known as the "Fish-hook of Mani."

About nine degrees north-west of Antares is a beautiful, easily seen double, known as Graffias, or Beta Scorpionis. The larger star of the pair is of a pale white colour, and of the second magnitude, while the companion star is of the sixth magnitude and of a pale blue colour. The two stars can be seen nearly thirteen minutes of arc apart. Jabbah or Nu is a beautiful triple star of the fourth magnitude, two degrees east of Beta. Its two companions are of the seventh magnitude. Sigma, one of the attendants or guardians of Antares, and about two degrees west of it, is a white, third-magnitude star, with a bluish, ninth-magnitude companion, situated in the body of the scorpion. Two degrees south-east of Antares is Tau, a star of nearly the third magnitude, the eastern attendant or guardian of the ruddy star. Epsilon, a star of the third magnitude, is situated seven degrees below Tau, and is the first star in the tail. Mu, the third star from Antares, and nearly five degrees below Epsilon, is also a third-magnitude star. Zeta, the next star below Mu, is situated where the curve turns suddenly to the east. It is a third-magnitude star, and a charming double, one of the components being reddish and the other bluish in colour.

To the north and east of Shaula and Lesuth, the twin stars in the uplifted sting, are two beautiful star clusters, about four degrees apart, known as 6 M. and 7 M. which can be very well seen with an opera glass. Nearly half-way between Antares and Graffias, or Beta Scorpionis, is a fine star cluster, 80 M., visible with

a small telescope. It is said to be one of the richest and most condensed masses of stars in the heavens. In May, 1860, a star flared up apparently in the centre of the cluster, and shone at first with marked brilliancy, but faded in less than a month into invisibility. On the east of this conspicuous cluster is a dark gap in the sky, a starless spot about four degrees wide. It is interesting as being the first "black-hole" or "coal-sack" noted by Sir William Herschel.

Ophiuchus and Serpens
(The Serpent-Bearer and his Serpent)

The intertwined constellations of Ophiuchus, the Serpent-bearer, and Serpens, the Serpent, lie on both sides of the equator, and occupy a space in the sky nearly fifty degrees in length and breadth, north of Scorpio and south of Hercules. They are supposed to represent a giant treading upon the scorpion and crushing in his hands an enormous writhing serpent, whose upraised head is just south of the Northern Crown. The double constellation, the outline of which is weirdly irregular, contains two stars of about the second magnitude, about thirteen of the third, and a number of the fourth, fifth, and sixth magnitudes, and may be seen from May to September.

The head of the giant is northward, and is near that of Hercules. It is marked by a fairly bright second-magnitude star, Alpha Ophiuchi, or Ras Alhague, the "head of the Serpent Charmer," situated at about five degrees east and two degrees south of Ras Algethi in Hercules, and nearly midway between Vega and Antares. His legs are braced wide apart, the right being immersed in the Milky Way, with the heel close to the tail of the

Scorpion, while the left foot is planted over its heart. The third-magnitude stars Beta, or Cheleb, and Gamma mark the right shoulder, while the fourth-magnitude star Chi indicates the left shoulder. Sabik, or Eta, a brilliant star of the third magnitude on the margin of the Milky Way, is in the right knee, and Zeta, also of the third magnitude, is in the left knee. The left hand, which grasps the serpent below the neck, is marked by the third-magnitude stars Delta and Epsilon. The right hand, which grasps the serpent near the tail, is marked by the fourth- and fifth-magnitude stars, Nu and Tau, while the feet are indicated by several small stars.

Although, as noted by Hill, Ophiuchus is not counted among the zodiacal constellations, a part of it lies across the ecliptic, so that the sun, which occupies twenty-five days from November 21st to December 16th, in passing from Libra to Sagittarius, spends sixteen days of the time in travelling through Ophiuchus.

Aratus thus clearly describes the figure:

His feet stamp Scorpio down, enormous beast,
Crushing the monster's eye and platted breast.
With outstretched arms he holds the Serpent's coils,
His limbs it folds within its scaly toils,
With his right hand, its writhing tail he grasps,
Its swelling neck, his left securely clasps,
The reptile rears its crested head on high
Reaching the seven-starred Crown in northern sky.

The head of the serpent—*Serpentis Caput*—lies about ten degrees south of the Northern Crown, and is marked by five stars grouped in the form of a capital X, two of the stars being of the third magnitude, one of the fourth, and two of the fifth. From its figure it is

sometimes called St. Andrew's Cross. Of the five stars, Beta and Gamma are in the feet of the X, Kappa in the centre, and Iota and Rho at the top. Winding down below this group are the third-magnitude star Delta, the second-magnitude star Alpha, in the serpent's neck about ten degrees below the head, and the third-magnitude star Epsilon in the body. Here the body of the serpent winds through Ophiuchus, and passing up on the eastern side of the giant to Aquila has one star of the third magnitude, Eta, in the coil adjoining Sobieski's Shield, and one of the fourth magnitude, Theta, which marks the tip of the tail—*Serpentis Cauda.*

Statius thus refers to the reptile:

> Vast as the starry serpent that on high
> Tracks the clear ether and divides the sky,
> And southward winding from the northern Wain
> Shoots to remoter spheres its glittering train.

According to Greek mythology, Ophiuchus represents the famous physician and father of medicine, Æsculapius, the son of Apollo and Coronis, who was instructed in the art of healing and hunting by Chiron, the most celebrated among the centaurs. He is said to have taken part in the expedition of the Argonauts to Colchis, and in the celebrated hunt of the Calydonian boar. In later years he became so skilled in practice, that, it is said, he not only cured all the sick, but often restored the dead to life. Whereupon, Pluto complained to Jupiter that he was so diminishing the number of the dead that his kingdom was in danger of being depopulated. Æsculapius having, at the earnest solicitation of Diana, just restored Hippolytus, the

son of Theseus, to life, Jupiter, fearing lest men, through his great skill, might contrive to escape death altogether, killed him with a flash of lightning, but afterwards, on the request of Apollo, placed him among the constellations.

It is related that at the birth of Æsculapius, the inspired daughter of Chiron uttered this prophetic strain:

> Hail, great physician of the world, all hail!
> Hail, mighty infant, who, in years to come,
> Shall heal the nations and defraud the tomb!
> Swift be thy growth! thy triumphs unconfined!
> Make kingdoms thicker, and increase mankind.
> Thy daring art shall animate the dead,
> And draw the thunder on thy guilty head:
> Then shalt thou die, but from the dark abode
> Rise up victorious, and be twice a god.

Ophiuchus is also identified with Laocoön, a son of Antenor, and priest of Neptune, who with his two sons, during the siege of Troy, was attacked and strangled by two sea serpents, because he hurled a spear into the side of the wooden horse. His death has formed the subject of many ancient works of art, and its story was frequently related by ancient poets, such as Sophocles, Virgil, and others. A magnificent group representing the father and his two sons, entwined by two serpents, is still extant in the Vatican.

The brightest star in Ophiuchus, known as Ras Alhague, the "head of the Serpent-charmer," is a sapphire-blue star with a minute ninth-magnitude companion of a pale grey colour. It marks the giant's head, and may be located by drawing a line from Arcturus to the head of the serpent, and prolonging it an

equal distance. It is forty-four light years distant, has a proper or cross motion of ten miles a second, and is receding from the solar system at the rate of twelve miles a second.

Ras Alhague rises a little north of east, and requires six hours and forty-six minutes to reach the meridian, when it is not quite three-quarters of the way up from the horizon to the zenith. It rises just after the sun sets in the middle of May, and culminates at 9 P.M., July 28th.

Delta Ophiuchi, or Yed, the third-magnitude star in the left hand of the Serpent-bearer, is yellowish in colour, and has a minute tenth-magnitude companion of a pale lilac hue. Sabik, or Eta Ophiuchi, the brilliant third-magnitude star in the right knee, is of a pale yellow colour, and has a small bluish companion of the thirteenth magnitude. The fourth-magnitude star, Lambda Ophiuchi, or Marfik, has a close bluish-coloured companion of the sixth magnitude. Just east of Gamma Ophiuchi is an interesting binary known as 70 Ophiuchi. It is one of the stars of the discarded asterism, "Taurus Poniatowski," the Polish Bull, introduced in 1778 by the Polish astronomer Poczobut, in honour of the King of Poland. It has a period of about eighty-eight years. The magnitudes of the two component stars are, approximately, fourth and sixth. Rho, the larger of the two stars in the left foot of Ophiuchus is of rather less than the third magnitude, and is situated just above Antares. It is noted as being the star around which Barnard discovered by photography a wonderful nebula, a filmy cloud of sufficient density to obscure the light of the near-by stars.

Alpha Serpentis, the leading star of the Serpent, is a pale yellow star with a minute fifteenth-magnitude

companion of a fine blue shade. It was known to the ancients by the name "Unuk al Hay," and by astrologers of the Middle Ages as "Cor Serpentis," or the "heart of the Serpent." Beta Serpentis, a delicate double star in the serpent's under jaw, is of the third magnitude and of a bluish colour, with a ninth-magnitude companion of a yellowish tinge. The star Theta Serpentis, or Alya, is a charming double, the components being of nearly the same magnitude and not over one-third of a minute apart. It is situated over the little constellation of Sobieski's Shield, on the border of the Milky Way, and may be found by drawing a line from Beta Herculis through Alpha Ophiuchi. Then, too, a line drawn from Eta in the right knee of the Serpent-bearer to Gamma in the Soaring Eagle will indicate the direction of the tail of the serpent.

On October 10, 1604, a white and surprisingly brilliant temporary star, discovered by Brunowski and often called "Kepler's Star," broke out in the constellation Ophiuchus, but, after shining for some time as bright as a star of the first magnitude, it rapidly faded, and disappeared entirely about the end of March, 1606. In the summer of 1910, a new comet was discovered by Rev. Joel Metcalf of Taunton, Mass., drifting near the star Gamma Serpentis. The comet was a rather insignificant object, but was bright enough in the latter part of August to be seen with the naked eye.

Lyra
(The Lyre)

Lying close to the edge of the Milky Way, south-east of the head of the Dragon, and west of the neck of the Swan, is the small, but beautiful constellation Lyra,

or the Harp. It occupies the region of the heavens towards which the solar system is travelling, the so-called "Apex of the Sun's Way," being probably fairly near the fourth-magnitude star Delta in the middle of the Harp. It is noted because of its lucida, the brilliant steel-blue star Vega or Alpha Lyræ, the glory of the summer sky. To the old Arabian star-gazers, it was known as the "Falling" or "Swooping Eagle," as contrasted with Aquila near-by, the "Flying" or "Soaring eagle," and on some old maps was shown as an Eagle with a harp slung around its neck.

Longfellow, in *The Occultation of Orion*, thus alludes to the constellation:

> I saw with its celestial keys,
> Its chords of air, its frets of fire,
> The Samian's great Æolian lyre,
> Rising through all the seven-fold bars,
> From earth unto the fixed stars.

In addition to Vega, Lyra contains one star of the third magnitude, five of the fourth, and a few of the fifth. It is easily located by a line drawn from Arcturus through the Northern Crown, which leads directly to the Swan, and in its course passes over the Lyre. Then, too, the three stars in the neck of Aquila—the so-called "Family of Aquila"—point directly to it. Of the six stars forming a figure resembling a lyre, four dainty ones are arranged in an oblique parallelogram close by Vega, and by which the latter may be easily recognised. And again, Vega, Deneb, and Altair, form a well-known triangle by which they are readily identified in the sky.

In mythology Lyra is the celestial harp, which

Apollo presented to Orpheus, the son of Œagrus and Calliope, and with which, instructed by the Muses, he charmed not only the wild beasts, but also the stones and trees upon Olympus, and even chained the rivers in their courses. While in search of his long-lost bride, a nymph named Eurydice, who died from the bite of a serpent, the skilled harpist succeeded in so charming the guardians of the Stygian realms that they allowed him to enter. So entrancing was the music of his magic harp, that it brought tears to the eyes of the Erinyes, the wheel of Ixion stopped, the marble block of Sisyphus stood still, and Tantalus forgot his raging thirst. Pluto and his consort Persephone, it is related, were so charmed that they promised to restore the beautiful Eurydice, on the condition that Orpheus would not look back while passing out of the nether world. To this he readily consented, but just as he was nearing the regions of the upper air, his desire to see that Eurydice was following, overcame him. Looking round he beheld her caught back into the infernal regions, and on frantically attempting to follow her, was refused admission, and never saw her again. His grief for her loss led him to wander aimlessly about the earth until his death, when his body was buried with divine honours at the foot of Olympus, while his lyre was placed by Jupiter among the stars at the intercession of Apollo and the Muses.

Shakespeare, in *The Two Gentlemen of Verona*, Act III., Scene 2, thus refers to it:

> For Orpheus' lute was strung with poet's sinews;
> Whose golden touch could soften steel and stones,
> Make tigers tame, and huge leviathans
> Forsake unsounded deeps to dance on sands.

Vega, or the "Harp-Star," the dazzling leader of the constellation, is the most brilliant star in the northern hemisphere, being close to the zero rank. And though Capella and Arcturus, its companions in its circuit around the pole, are its close rivals, it is surpassed in splendour by only three stars in the entire sky, namely, Sirius, Canopus, and Alpha Centauri, all southern stars. Canopus and Alpha Centauri, however, lie so far south that they cannot be seen in this latitude.

It is a star of enormous magnitude and shines one hundred times more brightly than the sun would were it as far off. It belongs to the sirian type of stars, and hence is a much more rarefied body than either Capella or Arcturus which belong to the solar type. Then, too, if the supposition that the solar stars are at their hottest stage is correct, Vega is not so hot as either of these stars. It has the distinction of being the first star whose spectrum was successfully photographed, Henry Draper having taken it in 1872. It has a proper or cross motion of about eleven miles a second. So distant is it—thirty-five light years—that although it is travelling towards the solar system at the rate of about ten miles a second, and the solar system is moving in its direction at the rate of twelve miles in the same period of time, half a million years or more must elapse before the sun and Vega pass by each other.

Some fourteen thousand years ago Vega was the north polar-star, and in consequence of that slow shift of direction of the earth's axis called *Precession* it will again occupy that position eleven thousand five hundred years hence.

This sapphire sun is about twenty degrees nearer the north star than Arcturus, and only seven degrees

more distant from it than Capella, the nearest of the bright stars to the pole. Like Capella, it is so far north that it can be seen in this latitude at some hour of every clear night throughout the year. An opera glass will show clearly its delicate sapphire hue, and also the two small, yet conspicuous, stars, Epsilon and Zeta, which form with it a beautiful little triangle. It has a telescopic, bluish companion star of the tenth magnitude revolving around it. It rises over in the far north-east, about three hours after Arcturus, and is on the opposite side of the pole from Capella. It rises nearly at the hour when Rigel, which it closely resembles in colour and magnitude, is setting a little to the south of west. It occupies nine hours in reaching the meridian, when it is very near the zenith. It rises when the sun sets, about the first week in May, and culminates at 9 P.M., August 12th. On any clear night throughout July and August, it may be seen shining with great brilliancy, directly overhead, between nine and ten o'clock.

According to Chinese-Japanese legend, Vega was called the "Spinning Damsel," who each year, on the 7th of July, was supposed to stand at one end of the Magpie Bridge over the Milky Way, if the weather was clear, awaiting the coming of her lover, the Shepherd-Boy star Altair. In the legend, the Shepherd-Boy fell in love with the Spinning Damsel, much to her father's anger, who banished them both to the sky, on opposite sides of the Milky Way, where the Shepherd-Boy became Altair, and the Spinning Damsel, Vega. It was decreed by the father that they should meet once a year if they could contrive to cross the celestial river. On the night of the 7th of July, their friends the magpies congregate at the crossing-point and form a bridge

over which the lovers pass. After twenty-four hours the bridge disappears, as the magpies return to earth, and so the lovers cannot meet again for another year. Serviss mentions that in Korea, should a magpie be found in its usual haunts on this day, the children stone it for shirking its duty.

According to Lafcadio Hearn, this story of the Star Lovers is the origin of the Japanese festival called Tanabata. Should it rain at the time set for the crossing, the meeting cannot take place, since the celestial river would become too wide to be spanned by the Magpie Bridge. Hence, rain falling on the Tanabata night is called the "Rain of Tears."

To the ancient Britons, Lyra was known as "King Arthur's Harp," to the early Christians as "King David's Harp," to the Persians as a "Lyre," and to the Czechs as the "Fiddle in the Sky."

About eight degrees from Vega, and next to it in order of brightness, is Beta Lyræ, or Sheliak, a white, third-magnitude star (3.4) and one of the most noted and interesting of short-period variables. During a period of twelve days, twenty-one hours, and forty-seven minutes, it passes through two minima, only the alternate of which are equal. At one minimum it fades to magnitude 3.9 and at the other to 4.5. It is always a naked-eye object, and its variations are readily recognisable. It is an easy double in a two-inch instrument, and a triple star in a three-inch. It was discovered to be a variable star by Goodricke in 1784, and belongs to that type in which the mutually eclipsing bodies are unequal and both bright. Olcott refers to it as one of the ten stars that are said to be pear-shaped. It may be found by drawing an imaginary line from Vega towards Altair, when it will pass between Beta and Gamma.

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PLATE VII. Ring Nebula in Lyra

Mount Wilson Solar Observatory

PLATE VIII. Dumb-Bell Nebula in Vulpecula

Epsilon, a yellowish coloured star of the fourth magnitude, situated on the frame of the harp close to Vega, is a very curious star, and is known as a "double double star." It can be divided into two stars by an opera-glass, or even by the unassisted eye. Viewed with a small telescope, each of the two components will be found to be again double. Gamma, or Sulafat, about two and a half degrees distant from Beta, is a lustrous, yellow star of rather less than the third magnitude. It is a spectroscopic binary, and has a minute distant bluish companion of the eleventh magnitude. Zeta also is a double star, and is situated about two degrees from Epsilon. It is a topaz-tinted star of the fourth magnitude, while its companion is greenish in colour, and of the sixth magnitude. The distance between the components is a little over two-fifths of a minute.

Standing on a line between the stars Beta and Gamma and about two-fifths of the distance from the former star, is the celebrated Ring Nebula (Plate VII.), the only object of its class that will show its characteristic form in a moderate-sized telescope. In a three-inch telescope, it presents a dim, misty, appearance, and is about the apparent diameter of the planet Jupiter. In a more powerful instrument the nebulous ring appears filled with excessively delicate nebula with a star-like condensation in the centre. Wolf finds that, owing to rapid rotation of the ring, the four gases composing it have become separated into four different layers. The smaller or innermost ring is composed of an unknown gas, the next layer consists of hydrogen, the next consists of helium, while the outermost ring consists of another unknown gas.

On the line between Hercules and Lyra is the radiant

and its position can be easily found by its three principal stars Alpha, Beta, and Gamma. The three stars are close together and form a straight line, about five degrees in length, which, running athwart the Milky Way, points in a northerly direction nearly to Vega, and in a southerly direction to Alpha and Beta Capricorni. The middle star is the brightest and is called Altair, and the lineal figure, the "Shaft of Altair." Sometimes these three stars have been mistaken for the three gems in the belt of Orion, although they are not so bright. They are never so alike as when late on a mid-October night Orion is coming up in the east and Aquila is going down in the west. The unevenness of the Aquila stars helps to distinguish them from the stars in Orion's belt, which are markedly uniform both in brilliance and spacing.

The Galaxy, or Milky Way, which is supposed to be a vast ring of enormously distant stars made up of subsidiary spirals extending around the celestial sphere, is especially brilliant in this constellation, where it spans the heavens, like a great dimly-luminous arch, in two distinct branches, Aquila's principal stars being near the eastern edge of the eastern branch.

Antinoüs, a youth of extraordinary beauty, in honour of whom the lower portion of the combined constellation was named, was born in Bithynia, and was a favourite of the Emperor Hadrian, being his companion in all his journeys. He was drowned in the Nile A.D. 122, and the emperor enrolled him among the gods. So great was Hadrian's grief that he caused a temple to be erected to his memory at Mantinea in Arcadia, and founded the city of Antinoöpolis on the eastern bank of the Nile in honour of him.

According to Greek fable the Flying, or Soaring,

Eagle was the bird of Jupiter which stood by his throne, the bearer of his thunder, about which Manilius wrote:

> The towering Eagle next doth boldly soar,
> As if the thunder in his claws he bore:
> He's worthy Jove, since he, a bird, supplies
> The heavens with sacred bolts, and arms the skies.

This famous bird is represented as bearing aloft in his talons a most beautiful boy, sometimes called Ganymedes, a shepherd-boy of Phrygia, whom Jupiter, desiring him for his cup-bearer in place of his daughter Hebe (who awkwardly tripped and fell on a solemn occasion, and was forced to resign her office), sent his eagle to seize and carry off from Mount Ida up to Olympus, the abode of the gods. Jupiter, it is related, compensated his bereaved parents, Tros (the builder of Troy) and Callirhoe, for their loss, by a pair of divine horses.

Tennyson, in his *Palace of Art*, thus describes the picture representing the legend:

> Or else flush'd Ganymede, his rosy thigh
> Half-buried in the eagle's down,
> Sole as a flying star shot thro' the sky,
> Above the pillar'd town.

Ganymedes has also been identified as Aquarius, the eleventh sign and twelfth zodiacal constellation.

The curious Oriental legend of the Star Lovers and the Magpie Bridge, with which this constellation and Lyra are connected, was related in connection with the history of the latter constellation.

The brilliant white star Altair, or Alpha Aquilæ, the chief star of the constellation, lies in the Milky Way,

about twenty degrees below Albireo or Beta Cygni, and on a line drawn from Arcturus through the head of Hercules. It is situated in the neck of the eagle and makes with Vega and Deneb a conspicuous acute-angled triangle, Altair being at the apex. It is a fraction brighter than the first magnitude, and belongs to the sirian type of stars, its colour showing it to be in an early stage of its existence as a glowing star. It has a distant tenth-magnitude companion of a violet tint.

Altair is only about fourteen light years distant, has a proper or cross motion of eight miles a second, and is approaching the solar system at the rate of over twelve hundred miles a minute, or more than six hundred million miles a year. Next to Sirius and Procyon, it is the nearest first-magnitude star visible from northern latitudes. It sends abroad ten times more light than the sun, but the earth receives about ninety billion times more light from the latter, by reason of its nearness, than it does from Altair. It is one of the stars from which the moon's distance is taken, for computing longitude at sea.

It rises almost eight degrees north of east, and takes six hours and a half to reach the meridian, when it is about two-thirds of the way up from the horizon to the zenith. In the middle of June it rises when the sun sets, culminates at 9 P.M., on September 1st, and is in view, early in the evening, until the middle of December. Ovid thus alludes to its rising:

> Now view the skies,
> And you'll behold Jove's hook'd-bill bird arise.

In astrology Altair was considered to be a star of ill omen, and portended danger from reptiles.

The uppermost star, next above Altair, in the row of bright stars, three abreast, already referred to as pointing to Vega, is called Gamma, or Tarazed, and the lowermost, Beta, or Alshain. Gamma is a golden-yellow tinted star of the third magnitude in the back of the eagle, and forms a pretty contrast with white Altair. Beta, a double star of a pale orange colour, in the neck of the eagle and the head of Antinoüs, has, there is reason to believe, grown dimmer in the last three hundred years, and is now of about the third and a half magnitude. Two third-magnitude stars, Delta and Lambda, the former in the southern wing and the latter in the left foot of Antinoüs, lie in a line extending towards Scutum.

About eight degrees below Altair, in Antinoüs's right shoulder, is Eta, a remarkable, short-period variable, which changes every seven days, four hours, fourteen minutes, and four seconds, from the third-and-a-half magnitude, to the fourth-and-a-half, and back again. Its variability was discovered by Pigott in 1784. It is supposed to be a spectroscopic binary, and its greatest brightness continues only forty hours. It is a star of a yellowish colour, easily followed with the unaided eye, and is best seen in the early autumn evenings. The greenish-tinted third-magnitude star Zeta, along with Epsilon of the fourth magnitude, about two degrees apart and twelve degrees north-west of Altair, marks the tip of the tail. Theta, a third-magnitude star, in line with the three stars, Alpha, Beta, and Gamma, is in the right wrist of Antinoüs. The variable star R, situated about midway between Zeta and Delta, is of a deep red colour, and in the space of 351 days changes from the sixth-and-a-half magnitude to the eleventh, and back again.

Sagittarius
(The Bow-man)

The ninth sign and tenth constellation of the zodiac, Sagittarius, the Archer, lies near the southern horizon, between Scorpio and Capricornus, in a region crowded with beautiful nebulæ and star clusters. It contains one star of about the second magnitude, ten of the third, and a number of the fourth and fifth magnitudes, and in it lies the most southerly point of the zodiac. The constellation may be seen during July and August and in the early hours of the evening in September. It represents a centaur, with the head and the shoulders of a man and the body and the legs of a horse, with bow drawn, aiming an arrow at the heart of the scorpion.

Longfellow, in his *Poet's Calendar*, thus refers to it:

> The Centaur, Sagittarius, am I,
> Born of Ixion's and the cloud's embrace:
> With sounding hoofs across the earth I fly
> A steed Thessalian with a human face.

The group of stars can be easily recognised by a little figure resembling a straight-handled dipper, turned upside down, popularly known as the "Milk Dipper," because it lies partly in the Milky Way. This little dipper was known to the ancients as the "Ladle," and is formed by five stars of the third and fourth magnitudes, namely, Zeta, Tau, Sigma, Phi, and Lambda and is quite conspicuous during August and September. The inverted bowl of a larger dipper is outlined by the stars Zeta, Sigma, Lambda, and Delta, of which Gamma forms a short handle. The two dippers are nearly seventy degrees south of Vega, and are about as far south of the equator as Vega is north of it. A line

drawn from Deneb through Altair will, if produced, pass through the centre of the constellation.

The upright, curved line of stars, on the right, formed by the second-magnitude star Epsilon, or Kaus Australis, the third-magnitude star Delta, or Kaus Meridionalis, and the fourth-magnitude star Lambda, or Kaus Borealis, represents the bent bow of the archer. Gamma, or Al-Nasl, a third-magnitude star, a little west of Delta, marks the arrow's tip. Whilst Zeta, or Ascella, a bright third-magnitude star, a little below Sigma, or Nunki, indicates the arrow drawn back by the right hand of the archer and about to be shot westward from the bow, which lies in the Milky Way. By a certain linking up of the stars, two bows can be outlined, one behind the other, the rear one displaying a broken arrow.

North of the fourth-magnitude star Tau, Pi of the third magnitude, and Omicron of the fourth magnitude, along with three smaller stars, mark the head of the centaur. Alpha, or Rukbat, and Beta, or Arkab, both fourth-magnitude stars in the left leg, lie too far south to be seen in this latitude.

The sun enters the constellation Sagittarius on December 16th, and occupies it until January 18th, reaching the most southerly point of its path on December 21st. On December 31st, when the sun is in the middle of the constellation, the earth is closer to the sun than at any other time, and is then travelling most rapidly in its course.

According to Greek fable, the Archer was the famous centaur, Chiron, son of Saturn and Philyra, who changed himself into a horse to elude the jealous enquiry of his wife Rhea. He was famed for his skill in medicine, music, and archery, and instructed in the

liberal arts some of the greatest heroes of his time. He taught Æsculapius medicine, Apollo music, and Hercules astronomy. Being accidentally wounded by his friend Hercules with an arrow that had been dipped in the blood of the Lernæan monster, Chiron, realising that the wound was incurable, prayed Jupiter to deprive him of immortality, that he might, by dying, be relieved from his excruciating pains. Jupiter granted his request, and translated him to a place among the constellations.

> Midst golden stars he stands refulgent now,
> And thrusts the Scorpion with his bended bow.
>
> OVID.

In astrology, Sagittarius is the House and Joy of Jupiter. Those born between November 22d and December 21st are said to be ruled by this sign. It is considered a lucky sign, and masculine. Dunkin says that Arcandum, an old astrologist, who published a book in 1542, declared that a person born under the sign Sagittarius, "is to be thrice wedded, to be very fond of vegetables, to become a matchless tailor, and to have three special illnesses"; but as the last attack of sickness is to befall the patient at eighty years of age, it is not of paramount moment.

The archer was the tribal symbol of Ephraim and Manasseh. Not far from Mu, a pale yellow multiple star of the fourth magnitude, in the north tip of the archer's bow, is the grand cluster 24 M, visible to the naked eye. A little south-west of Mu is the famous cluster 8 M, also a naked-eye object. It can be found by drawing a line from the star Phi to Lambda, and extending it an equal distance. It is said to be a cluster superposed upon a fine nebula. Two of the most

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PLATE IX. Star-Cloud and Black Holes in Sagittarius

marvellous so-called "coal-sacks"—dark spots where no stars appear—photographed by Barnard (Plate IX.), are in this cluster. To the north of this is the rich and celebrated nebula marked 20 M, discovered in 1764, and sometimes called the "Trifid Nebula," a large gaseous nebula of strange shape, traversed by dark rifts, as though it had been torn asunder by some wandering star drifting through it. The famous "Omega Nebula" marked 17 M, thus named from its alleged resemblance to the Greek letter Omega, is a fine, large, and bright object, easily seen with a small telescope.

Centaurus
(The Centaur)

Lying between Hydra and the far-famed Southern Cross is the large and brilliant constellation Centaurus, the Centaur. It is in the southern sky so low down that the main part of it can be seen only in southern latitudes. Some of its northernmost stars are, however, visible in middle latitudes from June to July. It is noted for having as its leader the nearest of all the stars, the celebrated Alpha Centauri, whose parallax was ascertained by Henderson in 1839.

Alpha Centauri is a brilliant white star of nearly the zero magnitude, ranking next to Canopus, and lies in the line of the Milky Way. It is a beautiful binary, the smaller component being almost of the first magnitude, with a period of revolution of about eighty-one years. It is four and a third light years distant, has a proper or cross motion of over fourteen miles a second, and is approaching the solar system at the rate of thirteen and a half miles a second. Beta Centauri is

a brilliant white star of nearly the zero magnitude, about four degrees from Alpha. It is eighty-eight light years distant, and has a proper or cross motion of over three miles a second. These two stars, neither of which can be seen in these latitudes, are in the forefeet of the Centaur, and are sometimes called the "Southern Pointers," because a line drawn from Alpha through Beta will point towards the Southern Cross, which is about thirty degrees from the South Pole.

Centaurus is further noted as containing the richest and most remarkable globular star cluster in the whole heavens. This famous cluster, which is known as Omega Centauri, is a closely compressed cluster of thousands of stars, and upon a clear dark night is visible to the unaided eye as a hazy star, in lustre similar to a star of the fourth or fifth magnitude. In the telescope it is a wonderful object, but can only be seen in the southern hemisphere. Like its northern rival—the Hercules cluster—it is populous with variable stars.

Hercules
(The Kneeling Hero)

The large and important but straggling group of stars lying below the head of the Dragon, east of Boötes and the Northern Crown, north of Ophiuchus, and west of Lyra, is known as the constellation Hercules. It is not a brilliant constellation, having no star brighter than the third magnitude, but is interesting telescopically on account of the many double stars, clusters, and nebulæ it contains. It is one of the oldest star-groups and in the early lists is often called the "Kneeler."

The constellation was intended to immortalise the

name of Hercules, who is usually represented as invested with the skin of the Nemæan lion, swinging in his right hand a brass club, the gift of Vulcan, and holding in his left an apple branch in which serpents are entangled.

Bryant, in *The Constellations*, alludes to him as:

Hercules with flashing mace.

The celebrated giant is figured as standing feet upward in the sky, with his left foot, pointed out by Gamma, on the head of the great dragon, and his head, indicated by the star Ras Algethi, nearly touching that of Ophiuchus. The group is most easily recognised by the striking figure, sometimes called the "keystone," made by the stars, Pi, in the right thigh, Epsilon and Zeta, in the abdomen, and Eta in the left thigh. The constellation, which is estimated to be about twenty million million miles distant, extends to within four degrees of the equator, and is best seen from May to October.

According to Greek fable, Hercules, one of the greatest heroes of remote antiquity, was the son of Jupiter by Alcmene of Thebes, a granddaughter of Perseus. While yet a babe in his cradle, the jealous Juno sent two serpents to destroy Hercules, but the infant hero strangled them with his own hands. He was educated by the centaur Chiron, and as he grew up was instructed by Amphytrion in driving a chariot, by Autolycus in wrestling, by Eurytus in archery, by Castor in fighting with heavy armour, and by Linus in singing and playing the lyre.

On the command of Jupiter, by the cunning artifice of Juno, he was subjected to the will of Eurystheus, his

elder half-brother, for the space of twelve years, and was promised immortality if, among other achievements, he performed twelve difficult tasks for Eurystheus, universally known as the "twelve labours of Hercules."

> Let Hercules himself do what he may,
> The cat will mew, and dog will have his day.
>
> SHAKESPEARE, *Hamlet*, Act V., Scene I.

Sometime after completing his twelve labours, Hercules unwittingly put on a tunic that had been steeped in the poisonous blood of the centaur Nessus, whom he had slain with a poisoned arrow. It caused him terrible torture, to escape which he ascended Mount Œta, where he erected a great funeral pyre, spread out the skin of the Nemæan lion, placed himself upon it, and ordered Philoctetes, a son of Pœas the shepherd, to whom he had given his bow and arrows, to set it on fire. When the pyre was burning, a cloud came down from heaven and, amid peals of thunder, carried him up to "many-peaked Olympus," where he was honoured with immortality, became reconciled to Juno, and married her daughter Hebe, for a time the cup-bearer of the immortals.

> Almighty Jove
> In his swift car his honour'd offspring drove;
> High o'er the hollow clouds the coursers fly,
> And lodge the hero in the starry sky.
>
> OVID.

The chief star of the constellation Ras Algethi, or Alpha Herculis, in the head of the giant, is a double star of the third magnitude, of especial charm and beauty. It may be easily found by drawing an imagin-

ary line from Pi through Delta, and continuing it for the same distance. Then, too, it may be known by its orange-red colour, and by a white star Ras Alhague, or Alpha Ophiuchi, about five degrees east of it, with which it makes a wide pair. It is an irregularly variable star, and at its minimum is of somewhat less than the fifth magnitude. Its variability was discovered by Sir William Herschel in 1795. Its companion star, which is about five seconds of arc distant, is of the sixth magnitude, and of an emerald or bluish-green colour. Ras Algethi forms an isosceles triangle with Beta or Kornephoros and Delta, two third-magnitude stars in the shoulder.

The constellation is teeming with beautiful double stars, which seem to display much more variety of colour than do single stars.

> Those double stars
> Whereof the one more bright
> Is circled by the other.
>
> TENNYSON.

The most interesting physical double in Hercules is Zeta, a third-magnitude star of a yellowish colour, with a companion of about the sixth magnitude, and of a bluish-green tint. It is situated in the belt, near Epsilon, between Gamma, in the Northern Crown, and Vega, and its distance is about twenty-three light years. It is a very close binary and the period of revolution is about thirty-four years. Its duplicity was first discovered by Sir William Herschel in 1782. Gamma, another double, of nearly the third magnitude in the right arm, is of a white colour, and has an eighth-magnitude companion of a lilac hue. Delta, also of nearly the third magnitude, is of a pale-green colour,

with a companion star of the eighth magnitude and of a bluish colour.

Mu, a yellowish star of the third-and-a-half magnitude in the left forearm, has an eighth-magnitude companion of a bluish colour, and is about thirty-one light years distant. Rho is a beautiful white star of the fourth and a half magnitude, with a green companion star of about the sixth magnitude. Kappa, or Marfik, a yellowish fourth-magnitude star, in the right hand, has a sixth-magnitude companion of a pale red colour. The star 95 is a double, peculiar in its colouring, in that one star is red and the other green, while the components are both of about the fifth magnitude.

Hercules has a remarkable cluster of stars (Plate X.) situated about one-third of the distance between the stars Eta and Zeta, east of and close to the Northern Crown. It is the most magnificent cluster visible to northern observers, and is known as 13 M (that is to say, the 13th in Messier's Catalogue), or the "Great Cluster in Hercules." It is one of the supreme marvels of the universe, and is surpassed in richness by only two clusters in the entire heavens, namely its southern sisters Omega Centauri and 47 Toucanis. On a very clear dark night it is just visible as a dim speck to the naked eye, and in a small telescope it looks like a small nebula, while with the aid of a powerful instrument it is resolved into a universe of stars. It is roughly spherical in outline, and there are crowded within its borders over six thousand stars, packed so closely together that the central part is simply a uniform blaze of light. According to Irving it appears to be surrounded by long, spirally radiating wisps of nebulous matter in which other stars are entangled. Recent photographs taken with the sixty-inch mirror of the Mount Wilson

Yerkes Observatory

PLATE X. Star-Cluster in Hercules

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PLATE XI. Lace Nebula in Cygnus

Observatory show, it is said, not six thousand, but sixty thousand stars. Halley, who discovered it in 1714, alluded to it as one of the six nebulæ known at that time. Like Omega Centauri, of which it is almost an exact duplicate, it abounds in variable stars.

Cygnus
(The Flying Swan)

Situated in the midst of the Milky Way, east of Lyra, and south of Cepheus, is Cygnus, the "Flying Swan," one of the finest constellations in the northern sky. It is represented by a figure of a star-spangled swan, with wide-spread wings, flying down the Milky Way, toward the south-west.

Smith, in *Come Learn of the Stars*, thus alludes to it:

> Yonder goes Cygnus, the Swan, flying southward,—
> Sign of the Cross, and of Christ unto me.

Cygnus is a prominent object in the summer night-sky, and contains one star of the second magnitude, five of the third, and a number of the fourth, fifth, and sixth magnitudes. It is visible from May to December, and is easily recognised by its most striking feature, the beautiful Northern Cross. The upright piece of the cross, lying parallel to the axis of the Milky Way, is over twenty degrees in length and is formed by the bright stars Alpha, Gamma, and Beta, together with a few faint stars, which also represent the outstretched neck, body, and tail of the flying swan. The arms of the cross and the outstretched wings of the "Bird" are marked by the stars Delta, Gamma, Epsilon, and Zeta. Sadr, or Gamma, the bright third-magnitude

star at the intersection of the upright and the cross-piece, is about eighteen degrees south-east of Vega, midst a rich stream of faint stars. This cross is larger and more perfect than the far-famed Southern Cross, a small constellation near the south celestial pole, although its stars are perhaps not so brilliant. The early Christians regarded it as the "Cross of Calvary." Olcott, in his scholarly work *Star Lore of All Ages*, thus beautifully alludes to it as it appears on Christmas eve:

> At nine o'clock, this brilliant cross of stars stands upright on the western hills, outlined against the sky, as if beckoning all beholders onward and upward. A beautiful symbol of the Christian faith, glorious, perfect, and eternal.

The constellation Cygnus is rich in interesting variables, and in it are situated the brightest parts of the Milky Way, in the northern hemisphere. The "great bifurcation," which reaches to Centaurus in the southern hemisphere, begins here. Between the stars Alpha, Gamma, and Epsilon, is one of the most remarkable dark gaps in the Milky Way, known as the "Northern Coal-sack."

According to some authorities, the constellation represents the swan into which Jupiter transformed himself, when, incognito, he visited Leda, wife of Tyndarus, King of Sparta. Others suppose it to be Cycnus, son of Sthenelus, King of the Ligurians, and an intimate friend and relative of Phaëthon, that unhappy youth with whom the horses of the sun ran away. The legend relates that while he was lamenting the untimely fate of Phaëthon and the melancholy end of his sisters, on the banks of the Eridanus, he was metamorphosed by Apollo into a swan, and placed among the stars.

In the tenth book of his *Æneid*, Virgil wrote:

> For Cycnus loved unhappy Phaëthon,
> And sung his loss in poplar groves alone,
> Beneath the sister shades to soothe his grief.
> Heaven heard his song and hastened his relief,
> And changed to snowy plumes his hoary hair,
> And winged his flight to sing aloft in air.

Deneb, or Alpha Cygni, sometimes called Arided, the leading star of the constellation, is a brilliant white star of rather less than the first magnitude. It is situated at the head of the cross and the root of the swan's tail, in one of the densest parts of the Milky Way, and is about six degrees farther north than Vega, and one degree farther south than Capella. A line drawn from Alpheratz, in the Square of Pegasus, to Vega, will pass close by it. Then, too, it forms with Polaris and Vega a right-angled triangle, the right angle being at Deneb.

Deneb is a star of the same general type as Sirius, though perhaps a little more advanced in development. It is one of the most remote of the bright stars, approximate measurements placing it at about 350 light years. It is approaching the solar system at the rate of thirty miles a second. It rises in the far north-east, and reaches the meridian, to the north of the zenith, in about ten hours. It rises when the sun sets about the middle of May, and culminates at 9 P.M., September 16th. Like Capella and Vega, it is visible at some hour of the night at all seasons of the year, in this latitude.

The star at the foot of the cross and in the beak of the swan is Albireo, or Beta Cygni, a fine double star of the third magnitude, notable on account of the

charming contrast in the colours of its components, which are about thirty-four seconds of arc apart. It is readily resolved by a small telescope, and is an easy object in even a strong binocular or field-glass. It is one of the most beautiful and attractive double stars in the entire heavens. The larger star is orange-yellow, and the smaller, which is a fifth-and-a-half magnitude star, is sapphire-blue. It is approaching the solar system at the rate of about fifteen miles a second.

The faint little star called "61 Cygni" is a most interesting double, famous as being the first star whose distance was (in 1838) accurately measured by the Prussian astronomer Bessel. The principal star is of a golden-yellow colour, and of about the fifth-and-a-half magnitude, while its companion is of the same colour, and of rather less than the sixth magnitude. It is barely visible to the naked eye on a clear night, but is easy to find with the aid of a binocular. It is situated on the opposite side of the cross from Vega, six degrees from Gienah or Epsilon in the right or east wing, and forms a fairly well-marked parallelogram with Alpha, Gamma, and Epsilon. 61 Cygni is one of the nearer stars in the sky, being only 10½ light years distant. It has a proper or cross motion of 49½ miles a second, a large speed as stellar motions go, and is approaching the solar system at the rate of thirty-nine miles in the same period of time.

About half-way between Deneb and Delta is Omicron, an orange-coloured fourth-magnitude star, which, in an opera-glass or field-glass, will be seen to have two companions of a bluish colour, one being of the fifth and the other of the seventh magnitude.

The constellation is replete with nebulous clouds, and contains many deeply coloured red and orange

Yerkes Observatory

PLATE XII. The North America Nebula in Cygnus

stars, hence this somewhat crowded portion of the heavens has been styled by some the "Red Region of Cygnus." Not far from Beta, in the neck of the swan, is the long-period variable star Chi Cygni. In a period of 406 days, which is gradually lengthening, it changes from the fourth-and-a-half to the thirteenth-and-a-half magnitude, reaching its maximum brightness in about 105 days. It is a fine red star, and its variability was discovered by Kirch in 1686.

The Lace Nebula, known as N. G. C. 6992 (Plate XI.) is one of the most beautiful nebulæ in the constellation, but unfortunately it is not within the range of small telescopes. Another remarkable object, invisible however to the naked eye, is the diffused nebula known as the "North America" nebula in Cygnus (Plate XII.). It was discovered by Wolf and received its name from its shape, resembling, as it does, the map of North America.

On the 24th of November, 1876, a temporary star of the third magnitude appeared in the constellation, but it faded so rapidly that in six days it was only of the fifth magnitude, afterwards apparently changing into a nebula.

The "Royal Family" of the sky—the celestial representatives of Cepheus, Cassiopeia, Andromeda, and Perseus—occupying, as they do, a conspicuous position in the night-sky of autumn, will receive attention in the next chapter.

O, sweet summer, pass not soon,
Stay awhile the harvest moon;
O sweetest summer, do not go,
For autumn's next, and next the snow.

CHRISTINA ROSSETTI, in *Seasons*.

CHAPTER IV

THE NIGHT-SKY OF AUTUMN

Referring to the vine-leafed autumn (*autumnus pampincus*), Virgil, addressing his second *Georgic* to Bacchus, writes:

> To thee his joys the jolly autumn owes,
> When the fermenting juice the vat o'erflows.

WHEN the sun arrives at the autumnal equinox, about the 23d of September, it marks the beginning of autumn in the northern hemisphere, and of spring in the southern hemisphere. On that day, as at the vernal equinox about the 21st of March, the sun is perpendicular over the equator, and day and night are of equal length all over the earth.

With the slow changing of the seasons the great, faint, summer groups of stars are slowly sinking in the west. The straggling Hercules and the brilliant Lyra are now low in the western sky, while the beautiful Northern Cross is a little west of the zenith. The stars of Boötes and the little circular group of the Northern Crown are about setting in the north-west, while over in the south-west are the three stars of the Flying Eagle which form the beautiful "shaft of Altair." Ophiuchus and his Serpent are low down on the western horizon, the Scorpion has disappeared in the south-west, and the Archer is fast sinking from view.

Almost exactly overhead, between the zenith and

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CHART III—AUTUMN NIGHT SKY

Polaris, and westward from Cassiopeia is Cepheus, with his gem the so-called "Garnet Star." South-east of the zenith, and nearly east of the Swan, is Pegasus, with its noble stellar figure, the Great Square of Pegasus. Close to the winged horse is Equus or Equuleus, the Foal, while west of the Square of Pegasus, and east of the Flying Eagle, is the little, diamond-shaped constellation, Delphinus, or Job's Coffin. On the meridian and on the ecliptic, below Pegasus, is the Water-bearer, and directly beneath it, near the horizon, and east of the meridian, is Fomalhaut, the leading star of the Southern Fish, a conspicuous object on clear autumn nights. West and north of the Southern Fish, heading westward, is the constellation Capricornus, the Sea-goat or Goat-fish. East of the Southern Fish, and south of the Water-bearer, is the small and unimportant southern constellation Sculptor. Skirting the horizon in the south-east is Cetus, the Whale, or Sea-monster, with its variable Mira, the "Wonderful." Directly above the whale is the long line of stars forming the constellation Pisces, or the Fishes, in which lies the vernal equinox. North-east of the Fishes, and above the head of the Whale, is the small but distinguished asterism Aries, or the Ram.

High in the eastern sky, approaching the meridian, on the opposite side of the pole from The Dipper, along the course of the Milky Way, is the constellation Cassiopeia, or the "Lady in the Chair," with its distorted celestial letter "W." Rising in the north-east is the Charioteer, marked by the brilliant yellow solar star, Capella, between which and Cassiopeia, east of the zenith, is Perseus with his Demon Star and Great Cluster. Above the Great Square of Pegasus, between it and Perseus, is the constellation Andromeda the

"Chained Lady," with its great and superb nebula visible to the naked eye on a clear night. Stretching from Polaris to Perseus, Auriga, and the Tiger, is Camelopardalis, the Giraffe. Low down on the northern horizon, The Dipper is approaching the lower meridian from the west, and above it are the body and head of the Dragon. Just emerging from the ground along the eastern horizon, a little north of east, is Taurus, with its standard first-magnitude star Aldebaran, and its wonderful star-groups, the Hyades and Pleiades. Passing through the zenith from north-east to south-west is the marvellously complex galactic belt, or Milky Way, along which may be found some of the most beautiful groups in the heavens.

Capricornus
(The Sea-goat)

The tenth sign and eleventh constellation of the zodiac, Capricornus, the Sea-goat, lies south-east of Aquila and west of Aquarius. It has no conspicuous stars, nor any very definitely outlined figure. As seen on a clear night the constellation has been likened to an inverted cocked hat, and again to the cross-section of a rowboat. And yet, after all, as Mrs. Martin in her *Friendly Stars* says, there is something about its dancing stars suggestive of a capering goat, if one does not try to be too definite. It is usually depicted as a sea-goat, headed westward, having the head and body of a goat, but the tail of a fish. Aratus thus describes it:

the goat
Dim in the midst, but four fair stars surround him,
One pair set close, the other wider parted.

Alpha Capricorni, or Algedi, and Beta Capricorni, or Dabih, two third-magnitude stars, two and a half degrees apart, in the right horn of the animal, are about twenty degrees south of Altair, and point towards it. A line drawn from Vega to the horizon, through Altair, will pass between them. Omega, a fourth-magnitude star marks the right knee of the kneeling Goat. The third-magnitude star Delta, or Deneb Algedi, and Gamma, or Nashira, are in the fish-tail. Below Beta is a pretty little triangle formed by the fifth-magnitude stars, Pi, Rho, and Omicron. In all, Capricornus contains four stars of the third magnitude, six of the fourth, and about ten of the fifth magnitude.

In mythology, the constellation was sometimes identified with Pan, the companion of Bacchus, and the god of everything connected with pastoral life. The legend relates that Pan, with some other deities, was feasting on the bank of the Nile, when the dreadful giant Typhon suddenly appeared in their midst. To escape his fury, they all fled, and assumed different shapes. Pan, taking the lead, plunged into the river, the upper part of his body assuming the form of a goat, and the lower part that of a fish. Desiring to preserve the memory of the caper, Jupiter turned Pan into a constellation in his metamorphosed state. In works of art, Pan is represented as a voluptuous being with horns, pug-nose, and goat's feet, sometimes in the act of dancing, and sometimes playing on the syrinx, or shepherd's flute.

Another legend associated Capricornus with the goat that belonged to the nymph Amalthea, daughter of the King of Crete. Amalthea and her sister, Melissa, as the story runs, fed the infant Jupiter with the goat's milk and honey. The father of the gods, as reward for their

kind and valuable services, placed the goat in the skies and gave one of its horns to the nymphs. This horn was endowed with the wonderful power of becoming filled with whatever the holder desired, and was ever after known as the celebrated horn of Amalthea, commonly called the "horn of plenty." According to an ancient Greek myth the constellation was the "Gate of the Gods," the region of the stars through which the souls of men passed on their way to the realms of the blest.

The star Alpha Capricorni, is a pretty, naked-eye double, and is easily separated with an opera-glass or binocular. The larger star is of the third magnitude, and the other of the fourth, and both are of a bright yellow colour. In a telescope each star is seen to be triple. Beta Capricorni is also a beautiful widely double star, in an opera-glass. Its magnitudes are third and sixth, and its colours, yellow and blue. Delta is a beautiful double, the larger star being of a yellowish colour, and its minute companion of a purple tint. It is interesting as marking the approximate position of the discovery of the planet Neptune by Le Verrier in 1846.

In astrology Capricornus is generally considered a feminine sign and unfortunate.

The sun enters the sign Capricornus about December 21st, but does not reach the constellation until January 18th, which it occupies until the middle of February. Dante thus alludes to it in the *Paradiso:*

> The horn of the celestial goat doth touch the sun.

The two stars in the head of the Goat, namely Alpha and Beta, pass the meridian, three-eighths of the way up from the horizon, at 9 P.M. on September 15th.

Delphinus
(Job's Coffin)

The beautiful and interesting little constellation Delphinus, the Dolphin, popularly known as Job's Coffin, lies south of Cygnus and east of Aquila. It is a finely marked diamond-shaped cluster, about ten degrees north-east of Altair, and is a fine sight in an opera-glass.

> The glory of the Flood and of the Stars.
>
> MANILIUS.

It is easily recognised by four stars in the head of the Dolphin, three of which are telescopic doubles and somewhat variable. A little south and west of these four stars, which are called Alpha, Beta, Gamma, and Delta, is another star known as Epsilon, which marks the tail. A line drawn from Polaris through Deneb, prolonged thirty degrees, ends at the Dolphin. The constellation has no stars brighter than the fourth magnitude.

In Greek mythology the starry Dolphin has been identified with the fish upon whose back Arion, the famous lyric poet and musician took his celebrated ride. Returning from Corinth to Sicily, where he had won some valuable prizes at a musical contest, he was seized by the rude sailors who coveted his treasures and meditated his destruction. Having been granted permission by his would-be murderers to play for the last time upon his cithara, he so charmed a school of the song-loving dolphins by his melodies that they crowded around the ship. Suddenly he threw himself into the sea, when one of the dolphins, acting as a life-saver,

took him upon his back and brought him safely to Tænarus, from whence he returned to Corinth.

Another legend relates that it was the dolphin—the messenger and favourite of Neptune—that carried the nereid Amphitrite to that deity, to become his bride. In works of art, Neptune (Poseidon) may be easily recognised by his attributes, the dolphin, the horse, or the trident.

The star Gamma is a fine double, and is of special interest on account of the beautiful contrasting colours of its components, which are eleven seconds of arc apart. The principal star is of the fourth-and-a-half magnitude, and of a yellowish colour, while the companion star is of the fifth-and-a-half magnitude and of a bluish-green colour. The slow companion star moves only about seven and a half degrees in one hundred years. Alpha, a star of the fourth magnitude, is a wide double, with a tiny companion star of about the tenth magnitude.

Equuleus
(The Little Horse)

Lying midway between the head of Pegasus and the Dolphin is a little cluster of stars called Equuleus, or Equus, the "Foal," or little horse. It is a reduplication of Pegasus, the winged horse, and its figure, like that of its brother, is in an inverted position. It is an ancient asterism, and was formed by Hipparchus from stars formerly belonging to the Dolphin. It may be known by the elongated, irregular trapezium, formed by four of its stars, only two of which are as bright as the fourth magnitude. In the *Rubaiyat*, Omar Khayyam, the astronomer-poet of Persia, thus alludes to the asterism:

The flaming shoulders of the Foal of Heaven.

In mythology, the asterism is said to represent the horse Celeris, which Mercury presented to Castor. Another myth associates it with the celebrated horse that sprang out of the rock which Neptune shattered with his trident, when contending with Minerva for superiority in Olympian magic.

Delta Equulei, a fourth-magnitude star with a fifth-magnitude companion, is noted because it possesses an extremely short period of revolution, which according to Hussey is about five and seven-tenths years. Epsilon is an interesting triple star of the fourth magnitude. Its companions belong to the fifth and tenth magnitudes respectively. The larger companion stands very close to the principal star, and is of interest on account of its period of revolution being only eleven years.

Equuleus is on the meridian about 9 P.M., September 24th.

Aquarius
(The Water-bearer)

The eleventh sign and twelfth constellation of the zodiac, Aquarius, the Water-bearer, is a large, but not very conspicuous straggling constellation lying east of Capricornus, south of Pegasus and Delphinus, and north of Piscis Australis. It contains no stars brighter than the third magnitude, but is important astronomically, owing to its position in the zodiac, and its telescopic richness. It has been represented from time immemorial by the figure of a man pouring out a stream of water from an urn. The constellation is best seen from August to November, and the major part of it

lies south of the ecliptic. The sun enters it about February 14th and occupies it until March 14th.

In Longfellow's translation of *Dante*, it is written:

> The sun his locks beneath Aquarius tempers,
> And now the nights draw near to half the day.

Situated at the northern limit of the constellation, intersected by the equator, is an exceptionally pretty group, forming a Y-shaped figure or a triangle, which marks the right hand and the overturned urn or water-jar of Aquarius. The bright stars forming the figure, which serves to readily distinguish the constellation, are Gamma, Eta, Pi, and Zeta. From this group can be traced small groups of faint stars, many of them in pairs and triples, which lead downward and eastward in wavering curves to Fomalhaut, a first-magnitude star in the mouth of the Southern Fish.

Aquarius is a natural emblem of the rainy season, and by the ancient Egyptians it was imagined that its setting caused the rising of the Nile. In mythology it is sometimes identified with Deucalion, son of Prometheus and Clymene, who, with his wife Pyrrha, escaped from the celebrated Thessalian nine-days' deluge in 1500 B. C. Some say it commemorates the youth Ganymedes, whom Jupiter snatched to Mount Olympus to be the cup-bearer of the gods.

In astrology it is a masculine sign and fortunate. Its natives are those born between January 20th and February 19th.

The chief stars in the constellation are Alpha, Beta, Gamma, Delta, and Phi, all of about the third magnitude. The leading star Alpha Aquarii, or Sadalmelik, is only one degree south of the celestial equator, and marks

the right shoulder, while Beta, or Sadalsuud, twelve degrees farther west, marks the left shoulder. A line drawn from Alpheratz through Markab, in the Great Square of Pegasus, and produced towards the south-west will pass near Alpha Aquarii. Five degrees east of Alpha is Gamma, in the right arm. Zeta, the central star of the little Y-shaped figure representing the water-jar, lies close to the celestial equator, and is a note-worthy long-period binary. The two stars are of the fourth magnitude, and of a white colour. They are separated by a little more than three seconds of arc, and the period of revolution is estimated at about 750 years. Delta, or Scheat, in the right leg, marks the radiant point of the meteors, known as the Delta Aquarids, which appear from the 27th to the 29th of July. With Beta and Gamma it forms an isosceles triangle, the vertex being at Gamma. About one degree west of Nu towards Epsilon, or Al Bali—two fourth-magnitude stars in the left forearm—is situated the remarkable "Saturn-like" planetary nebula, 4628. It was discovered by Herschel in 1782, and is approaching the solar system at the rate of about seventeen miles a second.

Piscis Australis
(The Southern Fish)

Lying south of Aquarius is Piscis Australis, the Southern Fish, a small constellation represented as a fish drinking the water poured out of the water-jar of Aquarius. It is an ancient asterism, and is marked out by the brilliant star Fomalhaut in the mouth of the fish, and a few fifth-magnitude stars to the west of it.

In Greek legend it is associated with the story of the adventure of Venus and her son Cupid, on the banks

of the Euphrates, with the famous Typhon, a terrible fire-breathing giant with a hundred heads, fearful eyes, and awful voices. To escape the monster, Venus threw herself with the infant Cupid into the river, and both were changed into fishes. Typhon is said to have been killed, finally, by Jupiter with a flash of lightning, and now lies under Mount Ætna.

The leader of the constellation is Fomalhaut, a star of the first magnitude, and the brightest star in this comparatively starless region of the sky. It is the farthest south of any very bright stars visible in this latitude. It may be seen in the southern sky from August to the end of December, and is a conspicuous object during the early evenings of autumn. An imaginary line drawn through the pointers to the pole star, and extended southward one hundred and twenty degrees, points to it. Then, too, the two western stars of the Great Square of Pegasus, namely Scheat and Markab, point in its direction.

Fomalhaut is of a reddish colour, and has a distant dull blue companion of the ninth-and-a-half magnitude. It is twenty-three and a half light years distant, and has a proper or cross motion of eight miles a second. It gives out about twenty-one times as much light as the sun. It was one of the four Royal Stars of astrology, and was also regarded as one of the four guardians of heaven. Astrologically it portended eminence, fortune, and power. It is a star much used by navigators in determining longitude at sea. At the Cape of Good Hope, and in similar latitudes, it is a zenith star. It rises in the far south-east and takes only four hours to reach the meridian, when it is less than one-fourth of the way up from the horizon to the zenith. It culminates at 9 P.M. on October 25th.

Pegasus
(The Flying Horse)

Pegasus, the Flying Horse, is a large and notable constellation situated north of Aquarius, east of Delphinus, and west of Pisces. It is a conspicuous feature of the autumn skies, and its chief object is a large quadrangular stellar figure called the Great Square of Pegasus. Each side of the square is nearly eighteen degrees in length, and the four stars which mark its corners, are Alpha Pegasi or Markab, Beta or Scheat, Gamma Pegasi, and Alpheratz the Alpha star of Andromeda. Alpheratz is the upper left-hand star of the square, the upper right-hand one is Scheat, the lower right-hand one is Markab, and the lower left-hand star is Gamma. The square is a prominent stellar landmark, and is sometimes called the "Big Diamond." It is all the more striking on account of its scarcity of stars, and is easily recognised during autumn and winter, a small triangle on the north-west corner helping to identify it. It marks the body of the horse, and the eastern third of the constellation.

Pegasus, often referred to as the "Half-Horse," is represented as a winged horse in an inverted position, flying westward, with his forefeet pawing the sky, although the group bears but little resemblance to a horse. According to fable it is the celebrated white-winged horse that sprang from the blood of the hateful Gorgon Medusa, after Perseus had cut off her head. Rising to the abodes of the immortals, he was tamed by Neptune or Minerva, and for a time was employed to carry thunder and lightning for Jupiter. He was given to Bellerophon, son of Glaucus, and grandson of Sisyphus, to aid him in conquering the Chimæra, a

hideous, three-headed, fire-breathing monster, part goat, part lion, and part serpent, whom Iobates, King of Lycia, had ordered him to destroy. With the aid of a golden bridle, which Minerva had given him, Bellerophon caught Pegasus while he was drinking at Pirene, a celebrated fountain at the famous Grecian city, spoken of in Horace as "Two-sea'd Corinth."

Bestride the horse, Bellerophon rode through the air, and killed the Chimæra with his arrows. The Chimæra vanquished, Bellerophon attempted to mount the heavens on the back of his winged steed. But Jupiter, angered at his presumption, sent a gad-fly to sting Pegasus, so that he dismounted his rider, who fell headlong to the earth. Pegasus, however, rid of his burden, continued his flight upwards and was placed by Jupiter among the constellations.

Pegasus was a great favourite with the Muses, because from his magic hoof-print gushed a fountain called the Hippocrene or Fons Caballinus, on the steep and rocky Acro-Corinthus, a mountain nineteen hundred feet in height, which served as the citadel of Corinth, and was in the words of Philip of Macedon, "one of the fetters of Greece." Serviss says that modern travellers may still see this fountain full of water. Bryant thus refers to it:

> The poetic steed
> With beamy mane, whose hoof struck out from earth,
> The fount of Hippocrene.

This fabled spring, at which, it is said, every poet must drink ere he can soar on Pegasean wing, was surrounded by a grove sacred to the Muses, which was adorned with some of the finest works of art. Spenser, in one of his poems, writes:

Then whoso will with virtuous wing essay
To mount to heaven, on Pegasus must ride,
And with sweet Poet's verse be glorified.

Pegasus is often seen represented in ancient works, along with Minerva and Bellerophon. Early Christians thought that the figure represented the ass on which Christ rode in triumph to Jerusalem. Longfellow, in his poem, *Pegasus in Pound*, represents the magic steed as straying into a certain quiet New England village, and being put into the pound:

Once into a quiet village,
  Without haste and without heed,
In the golden prime of morning,
  Strayed the poet's winged steed.

Thus upon the village common,
  By the schoolboys he was found;
And the wise men, in their wisdom,
  Put him straightway into pound.

And the curious country people,
  Rich and poor, and young and old,
Came in haste to see this wondrous
  Winged steed, with mane of gold.

On the morrow, when the village
  Woke to all its toil and care,
Lo! the strange steed had departed,
  And they knew not when or where.

But they found, upon the greensward,
  Where his struggling hoofs had trod,
Pure and bright, a fountain flowing
  From the hoof-marks in the sod.

The brightest star in Pegasus is Enif, or Epsilon, a wide, double star of a yellow colour, and of the second magnitude, with an eighth and a half magnitude companion of a violet hue. It lies about ten degrees east of the Dolphin, the diamond-shaped group of stars popularly known as Job's Coffin. Markab, or Alpha, is a white star of about the second magnitude, at the junction of the animal's wing and shoulder. It rises to the north of east, and occupies about seven hours in reaching the meridian, when it is nearly three-fourths of the way up from the horizon to the zenith. It is a spectroscopic binary, and it comes to the meridian at 9 P.M. on November 3d. Scheat, or Beta, in the left foreleg is an irregular variable, of about the second magnitude, and of a reddish-yellow colour. It is receding from the solar system at the rate of about four miles a second. A line from Alpheratz to Markab, prolonged an equal distance, passes through Zeta in the neck, and ends at Theta, which is at the top of the head. Enif is in the nose of the imaginary horse, while Gamma is situated on the extremity of its wing, and is receding from the solar system at the rate of about three miles a second. Alpheratz, with Gamma, and Caph, or Beta Cassiopeiæ, lie very nearly on the equinoctial colure or prime meridian of the heavens, which passes through the pole and the vernal equinox, and hence have been termed the "Three Guides."

The star 85 Pegasi, a few degrees below Alpheratz to the south-west, is one of the most interesting of binary systems. It takes rather more than twice as long as Kappa Pegasi (with a period of eleven and a half years) to complete its orbit. It was discovered to be a double star by S. W. Burnham in 1878.

Triangulum
(The Triangle)

Lying between Andromeda and Aries is the small but beautiful, ancient asterism known as Triangulum, the Triangle. The figure was also called Delta, or *To Deltoton*, from its likeness to the Greek letter Delta. A line drawn from Almaak in Andromeda to Hamal in Aries will pass through it.

> Beneath Andromeda, three lines compose
> The Triangle. On two sides measured equal,
> The third side less.
>
> ARATUS.

The corners of this long slim triangle are marked by the third-magnitude star Beta in the upper right-hand corner, the fourth-magnitude star Delta in the upper left-hand corner, and Alpha also a fourth-magnitude star at the apex or southern point of the figure. The star Alpha culminates at 9 P.M., December 6th.

A beautiful spiral nebula, 33 M, visible in a small telescope, lies just off a line from Alpha in the Triangle to Beta in Andromeda.

Triangulum is noted as marking the place where Piazzi on January 1, 1801, found Ceres, the first planetoid or minor planet to be discovered.

Aries
(The Ram)

The first sign and second constellation of the zodiac, Aries, the Ram, is a small but important constellation lying east of the northern fish of Pisces and north of the head of Cetus. The reverted head of the Ram is in the western part of the constellation, and can be recognised

by the two prominent stars Alpha, or Hamal, and Beta, or Sheratan, five degrees apart, with a fainter one, Gamma, or Mesarthim, drooping from them, the three stars forming an obtuse triangle. A small group of fourth- and fifth-magnitude stars, about ten degrees south-west of the Pleiades, marks the tail.

In the time of Hipparchus, who flourished in the second century B.C., Aries was the leader of the host of the zodiac, and the vernal equinox was just below Gamma Arietis. About A.D. 420, his leadership—as a constellation, not as a sign—was transferred to Pisces. The *sign* Aries remains the first of the zodiac, but owing to the precession of the equinoxes is occupied by the constellation Pisces, and will soon pass to Aquarius. As noted in Chapter I., the name "first point of Aries" is still applied to it by time-honoured usage.

First from the east, the Ram conducts the year.

A line drawn from Beta Tauri or El Nath to the Pleiades, and continued for about the same distance will reach Aries's head. The constellation may be seen every evening from late September to April, and the sun passes through it from April 16th to May 13th.

In mythology, Aries represents the ram with the golden fleece of Argonautic fame. Manilius thus refers to it:

First Aries, glorious in his golden wool,
Looks back and wonders at the mighty Bull.

According to legend Athamas, King of Thebes in Bœotia, had two children named Phrixus and Helle, by Nephele, whom he afterwards repudiated, and married the mortal Ino. Being persecuted by Ino, their

stepmother, who desired to sacrifice Phrixus to Jupiter, the two children were rescued by Nephele, and rode away through the air towards the east, upon the back of a ram which bore a golden fleece, the gift of Mercury. In their journey, Helle, Phrixus's sister, was so unfortunate as to drop off into the sea, between Sigeum and the Chersonesus, and was drowned. The sea was called after her, the Sea of Helle, or the Hellespont.

Longfellow, in his translation from Ovid, thus alludes to Helle's fall:

> The Ram that bore unsafely the burden of Helle.

Continuing his flight, the Ram bore the boy Phrixus to Colchis, at the eastern end of the Black Sea. In gratitude for his safe deliverance, Phrixus sacrificed the Ram to Jupiter, and gave the golden fleece to King Ætes, his protector, who fastened it to an oak tree in the sacred grove of Ares, under guard of a sleepless dragon. The fleece was afterwards carried away by Jason and the Argonauts, and the ram was placed by Jupiter among the constellations. Aries has also been identified with the ram into which Zeus changed himself to escape the pursuit of the giants.

Astrologically considered, Aries, like Scorpio, is the house and joy of Mars. It is a masculine sign, and is regarded as fortunate.

The chief star of Aries, marking his forehead, is Alpha, or Hamal, a yellowish star of the second magnitude. It lies near the moon's path, and is one of the stars by which terrestrial longitude is reckoned. It is about forty light years distant, has a proper or cross motion of eight miles a second, and is approaching the solar system at the rate of nine miles a second. It

rises in the north-east, about fifteen minutes before Capella, and takes about seven hours and a half to reach the meridian, when it is a little more than three-quarters of the way up from the horizon to the zenith. It culminates at 9 P.M., December 11th.

Beta, or Sheratan, is a white star, a little brighter than the third magnitude, and is situated about three degrees below Hamal, the two stars marking the base of the two horns of the Ram. The star Gamma, or Mesarthim, an easy double, is separable in a small telescope. The principal star is of the fourth magnitude and of a white colour, and the companion star is of the fourth-and-a-half magnitude and of a yellowish colour. Gamma was discovered to be double by Robert Hooke, while observing a comet near the star in 1664, but was not, as is sometimes stated, the first double star discovered, Riccioli having recorded the duplicity of Mizar, or Zeta, in Ursa Major, in 1650. Epsilon is a very close double, with a principal star of the fifth-and-a-half magnitude and of a pale yellow colour, and a whitish companion of the sixth magnitude. Lambda Arietis is a wide double, the larger star being white in colour and of the fifth magnitude, while the smaller star is of the eighth magnitude and of a bluish colour.

Perseus
(The Champion)

Directly north of the Pleiades, between Auriga and Cassiopeia, in a very brilliant part of the Milky Way, lies the rich and beautiful constellation Perseus. It is somewhat irregular in form, and about twenty-eight degrees in length, and is for the most part a circumpolar constellation. It can be easily traced by means of a curved line of stars running from Cassiopeia to Capella,

concave towards the Greater Bear, and usually termed the "Segment of Perseus." On old star-maps the constellation figure is represented as that of the Champion Perseus striding across the sky, with an enormous sword in his right hand, the head of Medusa in his left, and wings at his ankles. Aratus, in his *Skies*, as translated by Poste, thus alludes to the gallant hero:

> He in the north-wind stands gigantic,
> His right hand stretched towards the throne
> Where sits the mother of his bride.
> As one bent on some high deed,
> Dust-stained he strides over the floor of heaven.

Perseus is fabled to have been the son of Jupiter and Danaë. His mother's father, Acrisius, feared him and tried to make away with both him and his mother, by casting them, locked up in a chest, into the sea. They were rescued, however, by a fisherman, and carried to Polydectes, King of Seriphus (one of the Cyclades group of islands in the Ægean Sea), who received them kindly, and at whose court they afterwards lived. When Perseus was grown up, and looked not with favour on the king's proposed marriage with Danaë, he was ordered by Polydectes to bring him as a wedding gift the head of Medusa. Now Medusa, with her two sister Gorgons, was equipped with enormous tusk-like teeth, brazen claws, and golden wings, while hissing serpents crowned her head instead of hair. So hideous were the features of a Gorgon that to look at one, was to be turned into stone. Favoured by the gods, however, and accoutred for his perilous adventure, with Pluto's helmet of invisibility, Minerva's wonderful shield that was as bright as a mirror, and Mercury's winged sandals, he mounted the air and tracked the

Gorgon to her sea-girt cave near Tartessus. Finding the three Gorgon sisters asleep, and fearing to gaze in Medusa's face, he looked upon the image reflected in Minerva's polished shield, and with a backward stroke of his magic blade, he cut off her head and flew away with it in safety.

> The victor Perseus, with the Gorgon's head,
> O'er Libyan sands his airy journey sped,
> The gory drops distilled, as swift he flew,
> And from each drop envenomed serpents grew.

On his homeward flight through the air, Perseus beheld Andromeda, the Ethiopian maiden, chained to the rocks, and about to be devoured by the slimy sea-monster, Cetus. With lightning speed he rushed to her aid, turned the monster into stone by showing it the Gorgon's bleeding head, gallantly released the fair Andromeda, conducted her back to her father's court, and later married her. He gave the winged sandals and the helmet to Mercury who restored them to the nymphs and to Pluto, and handed the head of Medusa to Minerva, who placed it in the centre of her shield or breastplate. Some time after, at the request of Minerva, the noble pair (Andromeda and Perseus) were given a place in the sky, where they may be seen to this day—worthy and popular members of the so-called "Royal Family of Starland."

Algenib, or Mirfak, the Alpha of the constellation, is a lilac coloured star of the second magnitude, and is situated in the middle of the segment of Perseus, on the armour-clad breast of the hero, about ten degrees north of Algol. It is a beautiful star of the solar type, lying directly in the Milky Way, and resembles Altair in that it has a bright companion on either side. It is a fine

spectacle for the opera-glass, binocular field-glass, or small telescope. Algenib is about forty-four light years distant, has a proper or cross motion of one mile a second, and is approaching the solar system at the rate of seven miles a second. It passes the meridian about fifteen minutes after Algol, but is nine degrees farther north.

The most noted star in the constellation is Beta Persei, or Algol, the most remarkable periodic variable star in the heavens. It lies in a sort of offshoot, a little south-east of Algenib, and forms a triangle with it and Almaak, the star which marks the foot of Andromeda. It shines in Medusa's head, which is represented by a group of five or six stars hanging from Perseus's right hand, and is popularly known as the "Demon Star" or the "Winking Demon." It may be easily identified as being rather less than half-way upon a line drawn from the Pleiades to the distorted "W" of Cassiopeia. Then, too, another easy way to identify it is to let the four bright stars in the square of Pegasus represent a "stew-pan," and three trailing stars—Delta and Beta in Andromeda, and Algol in Perseus—represent its slightly bent handle, with Algol at the end of the handle. The stars, Beta, Andromedæ, Beta Persei, and Alpha Persei, form a greater "W" just beneath the smaller though more distinct "W" of Cassiopeia.

The variability of Algol was first scientifically noted by Montanari, an Italian, in 1669, but its periodicity was first accurately determined in 1783 by Goodricke, an English astronomer. Its period of revolution is two days, twenty hours, forty-eight minutes, and fifty-five seconds. It remains for the greater part of this time—that is for two days, eleven hours, and thirty minutes—at its maximum of nearly the second magnitude. Suddenly it begins to fade, and in about four and a half

hours, loses three-fourths of its light. When at minimum—its point of faintest brilliancy—it shines as a star but little brighter than the fourth magnitude. In about eighteen minutes it begins to brighten again, and in about the next four and a half hours regains its normal brilliancy. All of these variations are within the reach of the unassisted eye, and the most convenient time to watch them is through the hours of the early evening in autumn. Its singular variability is apparently due to its having a relatively dark sister, an enormous invisible body, about the size of the sun, circling around it with great speed, at a distance of only about thirty-two hundred thousand miles, and at regular intervals partly eclipsing it. The diameter of Algol is given as about one million miles, and that of its companion as about eight hundred thousand miles. To astrologers, Algol was known as the most unfortunate and dangerous star in the heavens.

Algol is a star of the sirian type and is approaching the solar system at the rate of two miles a second. No parallax has ever been found for it. It rises in the far north-east about an hour earlier than Capella, the shepherd-star, and occupies nine hours and twelve minutes in reaching the meridian, when it is not far from the zenith. It rises at sunset in the middle of September, and culminates at 9 P.M. on December 23d.

Midway between Algenib in the "Segment of Perseus" and Cassiopeia, is a magnificent double cluster of stars (Plate XIII.), visible to the naked eye as a small hazy patch of light in the Milky Way. It is known as the "Great Cluster of Perseus," and is considered to be the finest of all irregular star-clusters. It is sometimes called "Chi Persei," and forms, in the figure of the constellation, the "Sword-Hand of Perseus." When

Yerkes Observatory

PLATE XIII. Double Cluster in Perseus

Mount Wilson Solar Observatory

PLATE XIV. Crab Nebula in Taurus

seen in an opera-glass, or binocular field-glass, or better still in a two-inch telescope, this gorgeous double swarm of stars is a peculiarly beautiful and impressive object.

The star Eta Persei, on the right side of the hero's helmet, is a double star, the larger star of the two components being of the third and a half magnitude, and of an orange colour, while the smaller companion star is of the eighth and a half magnitude and of a bluish colour. Gamma, in the right side of the head, Epsilon, a double star in the left knee, and Zeta, a quadruple star in the left foot, are of the third magnitude, while Mu, in the right knee, is of the fourth magnitude.

The radiant point of the well-known yellow Perseid meteors, sometimes called the "Tears of St. Lawrence," fine displays of which are to be seen in varying numbers on the nights of August 10th to 13th, is in this constellation.

On the morning of February 22, 1901, there blazed out quite suddenly, in the neighbourhood of Algol, about midway between it and Delta Persei, a *Nova*, or new star—the celebrated Nova Persei. It was discovered by Rev. Dr. Anderson, an amateur astronomer of Edinburgh, and was the most brilliant Nova that has appeared since Kepler's in 1604. It shone with a bluish-white light, and within twenty-four hours had attained the brightness of a first-magnitude star. It began to fade in a few days, and in six weeks was invisible to the naked eye. Photographs obtained of it the following August showed a nebulous spiral encircling the star. Later the nebulosity disappeared, but the star is still visible as a telescopic body of the twelfth magnitude.

It is believed by most observers that the new star—previously an obscure body, an extinguished sun, so to speak—had, in its rapid journey through space, plunged into a vast invisible nebula, or had encountered a wide-

spread cloud of meteoric matter, the resultant friction of the incessant collisions heating its surface to incandescence, and so causing the outbursts of light. As happens to all variable and temporary stars, it became yellow as it faded, and finally turned red.

According to the estimate accepted by many, Nova Persei is approximately three hundred light years distant, so that the outburst actually took place about the year 1600, instead of in 1901, which was merely the year that the light was first seen on the earth. It may be mentioned, however, that some investigations, notably those of Bergstrand and Very, differently place the star's distance at from sixty-five to about one hundred and thirty light years.

Cassiopeia

(The Lady in the Chair)

On the opposite side of the pole from The Dipper, between Cepheus and Andromeda, lies the rich and interesting constellation, Cassiopeia, or the Lady in the Chair, one of the most attractive groups of stars in the northern sky. It is one of the six well-defined circumpolar constellations, that are always above the horizon in this latitude, and can be seen on any clear night throughout the year. Six of its chief naked-eye stars form a figure bearing a rude resemblance to a broken-backed chair—Cassiopeia's chair or throne—which stands on the Arctic Circle. Leaving out Kappa, a fourth-magnitude star on the front edge of the seat of the chair, the remaining five stars, when above the pole, roughly form a wide "W," with the open part turned towards the pole. Beginning at the right-hand or western end of the W, the stars are, Beta or Caph, Alpha or Schedir, Gamma, Delta or Ruchbah, and

Epsilon. When the stars are below the pole, they form a somewhat distorted capital "M." An imaginary line drawn from Mizar in The Dipper, through the pole, prolonged an equal distance, points to Ruchbah.

In mythological history, Cassiopeia, or more correctly Cassiepea, was the beautiful queen of Cepheus, King of Ethiopia, and mother of Andromeda, the maiden who was rescued from the sea-monster by Perseus. On the celestial maps, she is represented as seated in regal state on her gem-decked throne, drawing her robe over her shoulder with her right hand, and raising a palm branch to her head with her left. Near-by, on her right, is King Cepheus, on her left Perseus, her son-in-law, and above her Andromeda, her daughter. The head and body of the queen are in one of the brightest spots of the Milky Way, and her foot rests upon the Arctic Circle. By reason of the circumpolar motion of the stars, the vain and unhappy Cassiopeia, for half the time, occupies the "unqueenly attitude," alluded to by Miss Proctor, "of standing on her royal head," a punishment, among others, imposed upon her through petty spite of the Sea Nymphs, for boasting that she and her daughter were fairer than Juno or the sea-beauty Atergates. Aratus says:

> She head foremost like a tumbler sits.

The earthly Cassiopeia, or Cassiepea, is supposed to have been black, and is so described by Milton in the following lines from *Il Penseroso:*

> Hail, divinest Melancholy,
>
> . . . . . .
>
> O'erlaid with black, staid wisdom's hue;

Black, but such as in esteem
Prince Memnon's sister might beseem,
Or that starr'd Ethiop queen that strove
To set her beauty's praise above
The sea-nymphs.

The constellation Cassiopeia contains altogether about sixty stars visible to the unaided eye, including two of the second magnitude, three of about the third, and several of the fourth magnitude. The star Alpha Cassiopeiæ, or Schedir, in the breast, is a fine double star of about the second magnitude (max. 2.2, min. 2.8). It was discovered to be a variable star by Birt in 1831. The larger star is of a reddish colour, while the smaller companion star, which is of the ninth magnitude, is of a bluish tint. It is forty-seven light years distant and has a proper or cross motion of two miles a second. It is a star of the solar type, and culminates at 9 P.M. on November 18th. Gamma, also a star of about the second magnitude (2.3), is a gaseous star and has a companion of the eleventh magnitude. It is notable as being the first star discovered to contain bright lines in its spectrum.

Beta, or Caph, is a magnificent double star of about the second magnitude (2.4), in the back of the chair. The larger star is white in colour, and is so bright that the smaller companion star appears lost in its glare. It lies almost exactly on the equinoctial colure, or first meridian of the heavens, and is one of the so-called "Three Guides." It is approximately forty-four light years distant, and has a proper or cross motion of twenty-two miles a second.

Delta, or Ruchbah, the first star in the back of the chair, is a star of about the third magnitude (2.8), and

lies in line with Polaris and the true pole. The beautiful star Eta is an interesting telescopic binary, halfway between Alpha and Gamma, separable in a three-inch telescope, with a period of 328 years. The larger component is of the third-and-a-half magnitude, and of a white colour, while the smaller one is of the seventh-and-a-half magnitude, and of a rich, ruddy purple hue. It is the nearest star in the constellation, being only about sixteen light years distant. It has a proper or cross motion of eighteen miles a second, and is receding from the solar system at the rate of five and a half miles a second.

Epsilon, at the top of the back of the chair, is of the third-and-a-half magnitude, and Kappa, the star on the front edge of the seat, is of rather less than the fourth magnitude. Mu, a fifth-magnitude star, in the left elbow, is notable on account of its having the large proper or cross motion of ninety-eight miles a second. It is twenty-nine light years distant, and is approaching the solar system at the rate of sixty miles a second.

The constellation Cassiopeia is celebrated as being the one in which, near the little star Kappa, suddenly blazed out Tycho's very remarkable variable of 1572. This Tychonic Nova is the first nova or temporary star of which there is any really scientific record. It was observed by Tycho Brahé, the famous Danish astronomer, on November 11th, but was discovered by Schuler at Wittenberg in Prussia, who saw it dimly on August 6th. It was long known as Tycho's star, although sometimes spoken of as the "Pilgrim Star." When first seen it outshone the planet Jupiter, became as bright as Venus, and eventually was visible in full daylight. After a time, however, it began to fade,

I set thee
High for a star in the heavens, a sign and a hope for the seamen,
Spreading thy long white arms all night in the heights of the ether,
Hard by thy sire and the hero, thy spouse, while near thee thy mother
Sits in her ivory chair, as she plaits ambrosial tresses;
All night long thou wilt shine.

From Pěrses, the first-born of Perseus and Andromeda, the proud Persian kings are said to have claimed their descent.

The principal star of the constellation is Alpheratz, or Alpha Andromedæ, the north-eastern star in the square of Pegasus, and sometimes known as Andromeda's Head. It is a white, second-magnitude star, with a dark companion—revealed by the spectroscope—revolving round it, in a period estimated at about one hundred days. It is one of the "Three Guides" marking the equinoctial colure. A line drawn from Polaris through Caph, the outer-star of the "W" in Cassiopeia, continued for about thirty degrees, points directly to it. It rises in the north-east, and occupies nearly eight hours in reaching the meridian when it is seven-eighths of the way up from the horizon to the zenith. It rises when the sun sets on August 24th, and culminates at 9 P.M. on November 10th. Astrologically it portends honour and riches.

Gamma, or Almaak, a star of nearly the second magnitude (2.3), is interesting as being one of the most beautiful triple stars in the heavens, producing a fine contrast of colours. It is of a topaz-yellow colour, and has an emerald-green companion of the fifth magnitude which is in itself a double, having an eighth-magnitude

Yerkes Observatory

PLATE XV. The Great Nebula in Andromeda

(Of the seventeen novæ thus far known to have appeared in spiral nebulæ, eleven have been found in this famous spiral. Then, too, the discovery of novæ in spirals has led some astronomers to regard the latter as independent systems or "island universes." Moreover, recent spectroscopic observations lend support to the belief held by many, that the spiral nebulæ are made up of great and infinitely distant clouds of stars, and that they have enormous space velocities.)

companion of a bluish colour. Its duplicity was discovered by Johann Mayer in 1788, while Wilhelm Struve found its companion to be a close double in 1842. The principal star is easily separated in an ordinary telescope. The first and second companions form a binary with a period of about fifty-four years, but require a very powerful glass to show them properly. Almaak forms with the stars Algenib and Algol in Perseus an almost right-angled triangle opening towards Cassiopeia. An imaginary line from Polaris to Epsilon in Cassiopeia, continued for about an equal distance, points to it. The Andromedid or Bielid meteors, of about November 23d, radiate from its vicinity. It is approaching the solar system at the rate of nearly seven miles a second.

Beta, or Mirach, a second-magnitude star in the girdle, is of a yellowish colour, and about midway between it and Alpheratz is Delta, which marks the radiant point of a display of meteors on or about July 21st.

The most interesting object in the constellation is the famous nebula 31 M, commonly known as the Great Andromeda Nebula (Plate XV.), the first detailed observations of which were made by Simon Marius in 1612. It is near the star Nu, a short distance north of Mirach, and is the grandest nebula in the entire sky, with the exception, perhaps, of that of Orion. On a clear night, when the moon is absent, it can be seen with the naked eye, as a tiny wisp of white light. It shows up in an opera-glass, or a binocular field-glass, as a small dim cloud, and in a two-inch telescope has an elongated appearance, with a brighter spot in the centre. It is, in truth, a magnificent spectacle, and looks not unlike the planet Saturn, surrounded by its rings. It is often mistaken by the uninitiated for a

comet, and is the only true nebula that can be seen without optical aid. Newcomb relates that a skipper, fresh from a trip across the Atlantic, once visited the Harvard College Observatory, to tell Professor Bond that he had seen a small comet which remained in sight during his entire voyage. The object proved to be the Andromeda nebula. Its longer diameter is estimated to be more than half a million times the distance of the earth from the sun. It was formerly thought to be lens-shaped, but has turned out to be a huge spiral coiled in a plane only slightly inclined to the plane of sight. It is a white nebula, and according to Julius Scheiner gives a continuous spectrum without dark lines, which would imply that it is not a mass of incandescent gas, but must be composed of something in a solid or liquid form. Recent observations have led some astronomers to believe that it consists of myriads of small solid particles—meteorites—travelling round their common centre of gravity, in intersecting orbits, the constantly occurring collisions between the solid meteorites generating heat enough to cause them to glow. It is by far the largest and most conspicuous of the spiral nebulæ, and is approximately nineteen light years distant.

In August, 1885, a new star, or Nova, of the sixth magnitude suddenly blazed out close to the bright nucleus of the nebula. It remained visible with telescopes for about a year, and then faded from view.

Cepheus
(The Ethiopian King)

Lying across the meridian, between Cassiopeia and the Dragon's head, is the rather faint, but highly interesting, constellation Cepheus, the King. The entire

figure is about twenty degrees in length, its five brightest stars forming a rude square, surmounted by an isosceles triangle. It is sometimes called the "Little Diamond," in contradistinction to the "Big Diamond" of Pegasus, and may be readily found by carrying the eye from the "Pointers" through, or very close to, the North Star. The constellation contains only one star brighter than the third magnitude, namely, Alpha Cephei, formerly called Alderamin, which with Beta, or Alphirk, a bright third-magnitude star, lying about eight degrees nearer the pole, points almost directly to Polaris.

On the celestial maps Cepheus is represented as sitting near his wife Cassiopeia, in regal state, with a crown of stars upon his head, carrying a sceptre, extended toward Cassiopeia, in his left hand, and holding his robes with the right. His head lies in the Milky Way, while his left foot is on Polaris. Aratus thus alludes to the constellation:

> Cepheus himself just behind Cynosura
> Stands like one spreading both his arms abroad.

According to legend Cepheus was an Ethiopian king, son of Belus, husband of Cassiopeia, and father of Andromeda. He has also been identified by some with the godless and tyrannical Cheops, the builder of the Great Pyramid. He was one of the Argonauts, and was changed into a constellation after his death.

The brightest star in the constellation is Alpha a second-and-a-half magnitude star (2.6), in the King's right shoulder. It will be the north polar-star about fifty-six hundred years hence. Beta, a white, third-magnitude star (3.3), in the girdle, is a beautiful telescopic double with an eighth-magnitude companion of a

bluish colour. The star Delta is an interesting variable (max. 3.7, min. 4.6), with a period of five days, eight hours, forty-seven minutes, and thirty-nine seconds. Its variability was discovered by Goodricke in 1784. It is a typical example of the Cepheid variables, which, unlike the Algol variables, have no period when the brightness is constant, the light-changes being continuous. It is also an easy telescopic double, the larger component being of a deep yellow colour, while the smaller companion star, which is of the seventh and a half magnitude, is of a bluish tinge.

The star Mu, about half-way between Alpha and Zeta, famous as Sir William Herschel's "Garnet Star," is the reddest naked-eye star in the sky. It is an interesting variable, the variations of its light lying between the fourth and sixth magnitudes, but in irregular periods. It is a fine object in an opera-glass or binocular field-glass. During the latter part of June, a number of small meteors radiate from a point near Gamma, a fourth-magnitude star which marks the left foot of the King.

> Glide on in your beauty, ye youthful spheres,
> To weave the dance that measures the years;
> Glide on, in the glory and gladness sent
> To the furthest wall of the firmament—
> The boundless visible smile of Him
> To the veil of whose brow your lamps are dim.
>
> BRYANT, *The Song of the Stars.*

CHAPTER V

THE NIGHT-SKY OF WINTER

Like silver lamps in a distant shrine,
The stars are sparkling bright.

W. C. Dix.

With the passing of the autumn months the interesting summer constellations sink steadily lower in the western heavens, while in the east the brilliant winter groups, in order, rise to take their place. During the long nights of winter, the whole evening sky becomes filled with resplendent stars. Throughout the silent watches, lovely in their individuality, charming in their friendliness, dazzling in their splendour, enchanting in their beauty, they are, as Elgie says, magnificent, sublime!

The winter branch of the Galaxy or Milky Way, with its serpent-like streams of star-mist involving in its windings many of the constellations, stretches across the sky from south-east to north-west, a little north of the zenith. High up in the south-south-east, with its centre on the equator, is the magnificent Orion, bejewelled with seven brilliants, and universally regarded as the most splendid of all the constellations:

Whoso kens not him in cloudless night
Gleaming aloft, shall cast his eyes in vain
To find a brighter sign in all the heaven.

Above Orion—the Warrior of the ancient Mayas of Yucatan—are the beautiful Heavenly Twins astride the ecliptic, and high overhead the Charioteer, principally noted for its glorious lucida Capella with its attendant kids. Toward the west, on the meridian, is the threatening Bull backing across the heavens, with its interesting groups, the glittering Pleiades and the tristful Hyades, and the blinking, ruddy Aldebaran, the standard first-magnitude star. Under the mighty Orion are the faint groups, Lepus, the Hare, with its Crimson Star, and Columba, or Noah's Dove. Near-by, on the left, are the brilliant Dog Stars—the irradiant bluish-white Sirius, in the Greater Dog, the brightest star in the whole firmament, and the great, white Procyon, in the Lesser Dog.

The Greater Bear is seen steadily pursuing his journey up the slope of the north-east sky, while exactly on the opposite side of the pole is the bright W-shaped group Cassiopeia. Bordering the Greater Bear on the south and east are the very faint little groups of the Lynx or Tiger, and the Lesser Lion, while over in the north-west, north of Pegasus, is the Lizard. The Lesser Bear is seen hanging head downward, with the pole star at the tip of its tail, and near the horizon, in the hollow of The Dipper, are the Hunting Dogs, with the bright Cor Caroli. On the meridian, between the Charioteer and the pole, is the barren-looking constellation of Camelopardalis, the Giraffe, while below the pole, reaching down almost to the northern horizon, is the great Dragon.

In the east, the Lion, with its "Sickle" and beautiful white star Regulus, is emerging from the ground, while just west of it, along the ecliptic, is the wonderful Præsepe, or Bee-hive Cluster, in the constellation of

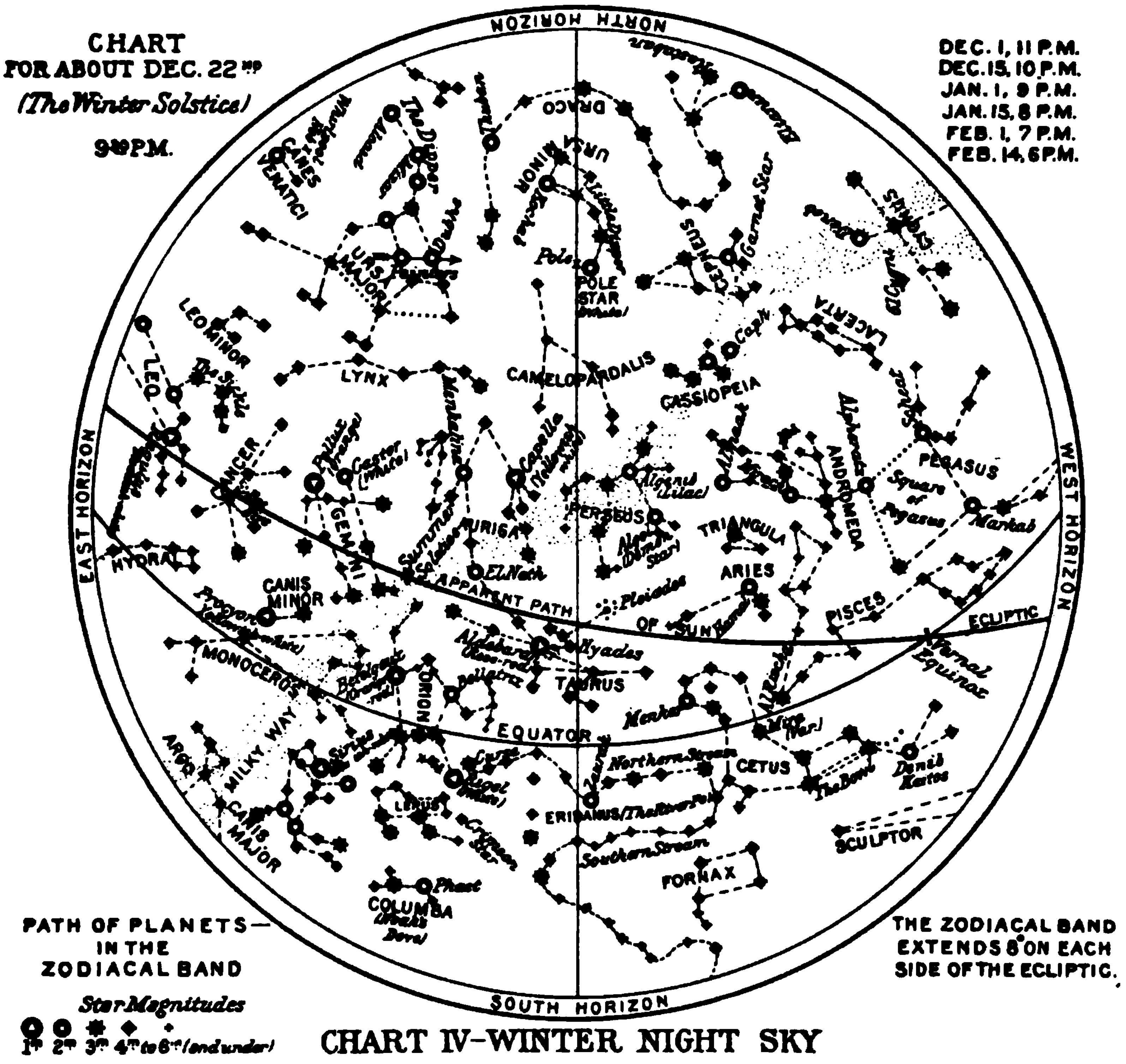

CHART IV—WINTER NIGHT SKY

the Crab, the faintest of all the constellations of the zodiac. In the south-east, the head of Hydra, the great Water-snake, has just risen, soon to be followed by the lonely rusty-looking Alphard, in the reptile's heart. Stretching from the Water-snake to Orion are a number of faint stars, which make up the little-known group of Monoceros, or the Unicorn.

Nearly overhead, just west of the meridian, is the champion Perseus, while west of him, and below Queen Cassiopeia, is the Princess Andromeda, and between the Queen and the Dragon is Cepheus, the King—a truly Royal Family, this "harassed house of Cepheus." South of Andromeda, and about half-way between the zenith and the western horizon, are Aries, the Ram, and the Triangle, while south-westerly from these is the constellation Pisces, the Fishes, now the leader of the zodiac. South of the Fishes and the Ram is the broad constellation Cetus, the Whale, in the neck of which, but usually invisible to the naked eye, is its most interesting star, the celebrated variable Mira. Low down towards the southern horizon will be seen part of the long, winding, starry river Eridanus, the Mississippi of the sky. Below Eridanus and the Whale is the unimportant southern constellation Fornax, the Chemical Furnace.

Already the poetic Eagle, the Water-bearer, and the Goat-fish have wholly withdrawn from the evening sky, and with the disappearance from view of the Winged Horse with its Great Square, which is slowly approaching the western horizon, and of the Northern Cross, which, upright in the north-west, is gradually sinking below the ground, the transformation of the summer into the winter sky will be complete.

Cetus
(The Whale)

Lying below Pisces and Aries, westward from Orion and almost entirely south of the equator, is Cetus, one of the largest constellations in the heavens. It is about fifty degrees in length, and from twenty-five to more than forty degrees in breadth. It is represented as a huge sea-monster, making his way eastward, and is often called the Whale, although it greatly resembles a walrus. The head is marked by a small pentagon of stars, namely Alpha, or Menkar, Gamma, Xi, Mu, and Lambda, directly below Aries, and is the only part of the creature above the equator. It is readily identified from the fact that the V of Hyades points to the stars Alpha and Gamma, which are only about five degrees apart. Besides, Alpha Ceti forms an equilateral triangle with the Pleiades and Alpha Arietis. The body of the monster is marked by a kite-shaped figure formed by the stars Beta, Eta, Theta, Zeta, and Tau, while the tail is indicated by Beta and Iota.

The principal stars of the constellation, visible from October to February, form the outline of a lounge-chair, or of an easy chair with the back falling backwards. Then too, four of its western stars of the third magnitude form an inverted bowl, a little larger than that of the Archer's so-called milk dipper. Altogether Cetus contains two stars of the second magnitude, six of the third, seven of the fourth, and about twenty-four of the fifth.

In Greek mythology, Cetus is the dusky sea-monster sent by Neptune to devour Andromeda.

> The south wind brings her foe
> The ocean beast.
>
> ARATUS.

It was turned to stone on beholding the bleeding head of Medusa which Perseus held before it. To commemorate the valour of the gallant hero, it was afterwards placed among the stars.

Alpha Ceti, or Menkar, the leader of the constellation, but no longer its brightest star, is in the nose of the imaginary whale. It is a beautiful, orange-coloured star of the second-and-a-half magnitude, with a fifth-and-a-half magnitude star of a bluish tint in the same field. It is an interesting object, but not a true double.

The lucida of Cetus is now Beta, sometimes called Diphda, or Deneb Kaitos. It is a yellowish star of the second magnitude and marks the south-western part of the constellation, and the tail of the whale. When it passes the meridian, it is about one-third of the way up from the horizon.

The most wonderful object in Cetus is the star Omicron, situated in the middle of the Whale's neck, and commonly known as Mira, the "Wonderful." It is a notable variable with an average period of about 331⅓ days. Its variability was discovered by David Fabricius, an unprofessional Dutch astronomer, on August 13, 1596, and it bears the distinction of being the first variable star of which there is any recorded observation. It is the type of the numerous class of stars known as long-period variables. At its maximum its spectrum shows the presence of glowing hydrogen. Like most variables, it is of a reddish colour, especially when fading. Its variations are more or less irregular both in period and brightness. It has a maximum varying from the second to the fifth magnitude, and a minimum varying from the ninth to the tenth magnitude. For five months, on the average, the star is invisible to the naked eye. It then slowly reappears, increasing in

brightness, until in three months it reaches its maximum of brilliancy. It remains stationary for about two weeks, and then fades away, for about three months, sinking again so low as to be invisible except in the telescope. At its best it outshines the North Star. It reaches its greatest brilliancy for 1914 in April; for 1915 in March; for 1916 in February, etc. So far the variations of Mira, and of long-period variables generally, remain unaccounted for. Whether the irregularities may not be, like the maxima and minima of sun-spots, phases of some general law, is one of the most interesting problems of modern astronomy.

Omicron, or Mira Ceti, is about twenty-three light years distant, has a proper or cross motion of nearly five miles a second, and is receding from the solar system at the rate of fity-four miles a second.

Tau Ceti, the south-east star in the inverted bowl, is of the third and a half magnitude. It is only nine and four-fifths light years distant, and has a proper or cross motion of seventeen miles a second. Zeta, the north-east star in the bowl, is an optical double, the principal star being of the third and a half magnitude and the companion star of the ninth. The star Gamma, six degrees west of Alpha, is a very fine double. The larger star is of the third and a half magnitude and of a yellowish colour, while the smaller star is of nearly the sixth magnitude, and of a bluish shade.

Pisces
(The Fishes)

The constellation Pisces, the Fishes, is the twelfth sign and first constellation of the zodiac. It is a rather large but dull-looking constellation, occupying a triangular space, directly above Cetus, and south of

Andromeda and Pegasus. It has no conspicuous stars, but is important because of its position, as owing to the precession of the equinoxes, it now occupies the place of the first sign (Aries), and is the leader of the zodiac. In it lies the vernal equinox, or the point where the sun crosses the equator on its way north in the spring. The prime meridian of the heavens passes through this crossing-point of the ecliptic and the equator, and from it the right ascension of all the stars is reckoned.

The constellation is usually represented on celestial maps by the figure of two fishes, quite widely separated, but held fast by long ribbons attached to their tails, and tied in a knot, which rests on Cetus's neck, and is marked by the star Al Rischa. The Northern Fish is represented by a group of fourth-magnitude stars between Aries and Andromeda, and the Western Fish by a "circlet" or lozenge-shaped figure traced by seven fourth- and fifth-magnitude stars, between Pegasus and Aquarius.

> The Fishes float, one ever uppermost.
>
> . . . .
>
> Both are united by a band.
> Their tails point to an angle
> Filled by a single goodly star.
>
> ARATUS.

A line drawn from Alpheratz to Gamma Pegasi is parallel to the body of the "Northern Fish," while another line from Gamma Pegasi to Markab is parallel to the "Western Fish."

In all, Pisces contains one star of the third magnitude, ten of the fourth, and about eighteen of the fifth.

In the early legends the Southern Fish—Piscis Australis—was the parent of the Northern and Western

Fishes, and fable associates all three with the story of Venus transforming herself and her son Cupid into fishes to escape the fury of the giant Typhon, when he assailed the gods on the banks of the Euphrates. To commemorate the event, Minerva placed two fishes among the constellations.

In astrology, Pisces is the House of Jupiter and the Exaltation of Venus. It is the ruling sign for those born between February 19th and March 20th. Like Scorpio, it is a feminine sign and unfortunate. As Olcott relates, a fish was always the symbol of the early Christian faith, and the figure may be seen in many of the stained-glass windows in the churches of to-day.

The chief star in the constellation is Al Rischa, or Alpha Piscium, a third-magnitude star in the knot where the two ribbons binding the fishes together are tied, and is sometimes called the "Knot Star." It is a beautiful double, about seven degrees above and to the right of Mira, but the components are so near each other as to be somewhat difficult with a three-inch telescope. The components have a separation of only two and a half seconds of arc, and the distance appears to be decreasing. The principal star is of a pale green colour, and the companion star, which is of the fifth magnitude, is of a bluish colour. It culminates at 9 P.M., December 7th.

From Al Rischa, the stars diverge in winding lines northward to the figure of the Northern Fish, and westward to the Western Fish. Zeta Piscium is an easy and pretty double lying between Mu and Epsilon, in the ribbon leading from the Western Fish. The principal star is of the fifth-and-a-half magnitude and white in colour, while the companion star is of the sixth-and-

a-half magnitude, and of a greyish colour. Psi Piscium, in the Northern Fish, is also an easy double; both components being white in colour, and of the fifth-and-a-half magnitude.

Lacerta
(The Lizard)

Lacerta, the Lizard, is a small, inconspicuous asterism, introduced by Hevelius at Dantzig, in the latter part of the seventeenth century. It is situated in the space between Cepheus, Cygnus, Pegasus, and Andromeda, and contains no stars brighter than the fourth magnitude. It marks the radiant point of the Lacertid meteors, and culminates at 9 P.M., April 13th. It is notable as being the asterism in which a new star—Nova Lacertæ—flared up in 1910. The Nova was discovered by the Rev. T. E. Aspin, on December 30th, and at its greatest brightness had attained to about the fifth magnitude.

Camelopardalis
(The Giraffe)

Lying between Auriga and Ursa Minor, is the faint straggling constellation Camelopardalis, the Giraffe. It was introduced by Hevelius in the seventeenth century, and is altogether dull and unimportant. It sprawls over a large area of sky, and contains no stars brighter than the fourth magnitude. It was supposed by Bartsch to represent the camel that carried Rebecca to Isaac.

Taurus
(The Bull)

Underneath Auriga and Perseus, between Aries and Gemini, lies Taurus, the Bull, the second sign and third

constellation of the zodiac. It is visible in the evening sky from September until the following May. It is one of the most notable of all the constellations, and was originally the leader of the celestial hosts. The stellar Ram succeeded next, and now the Fishes lead the year, soon to be followed by Aquarius. Virgil thus wrote of it, as early as the century preceding the Christian era:

> The milk-white Bull with golden horns
> Leads on the new-born year.

Among the finds in the excavations at Thebes is a sepulchre on the walls of which Taurus is portrayed as the first of the zodiacal signs. Over four thousand years ago it marked the vernal equinox. The great Tauric festival of the Druids, a survival of which is the festival May Day, commemorated the entrance of the sun into this constellation.

On celestial maps the Bull represents the animal that Orion is supposed to be hunting through the heavens, although little besides the head, horns, and forelegs have reached the sky. It is depicted as charging down upon the mighty hunter, albeit it rises backward, and, as if continually on the defensive, backs all the way across the heavens (Frontispiece). The constellation contains within its border two conspicuous star-groups —the Hyades and the Pleiades—besides a number of notable stars. Altogether, it has one star of the first magnitude, one of the second, two of the third, eleven of about the fourth, and a great number of the fifth and sixth.

In Greek fable it is the Bull which carried the fair Europa across the seas to Crete. Europa was the daughter of Agenor, King of Crete (twin brother of

Belus), and from her Europe took its name. Her surpassing beauty charmed Jupiter, who assumed the form of a snow-white bull, and mingling with the herds of Agenor, approached her, as she and her maidens were sporting on the sea-shore and gathering flowers. Europa caressed the animal, and encouraged by his apparent tameness, had the temerity to mount his back. Jupiter, taking advantage of the situation, dashed into the sea and swam away with her in safety.

In his *Palace of Art*, Tennyson, who like Virgil loved astronomy, thus refers to Europa:

> Sweet Europa's mantle blew unclasp'd,
> From off her shoulder backward borne:
> From one hand droop'd a crocus; one hand grasp'd
> The mild bull's golden horn.

In the Ducal Palace at Venice, in the same room with the picture of Bacchus and Ariadne by Tintoret, once one of the noblest pictures in the world, is a celebrated painting by Paul Veronese, depicting the kidnapping of Europa.

The "Hyades" group, a beautiful V-shaped cluster in the face of the imaginary Bull, is one of the best known star-groups in the heavens. It forms one of the most striking features of the winter night-skies, and is a fine sight with an opera-glass or a good field-glass. It is much more spread out than the Pleiades group, and is composed of brighter stars. All told, it contains one star of the first magnitude, five of the fourth, four of the fifth, and a few of the sixth.

The Hyades were the seven daughters of Atlas and Æthra, and together with their half-sisters, the Pleiades, were called the Atlantides. According to one legend, they were entrusted by Jupiter with the care of the

infant Bacchus, and were afterwards rewarded by him with a place in the sky. They were associated by the ancients with the ushering in of the rainy season, and were known by classic writers as the "rain stars." Homer and Pliny alluded to them as causing storms and tempests both on land and sea. There is reason to suppose that their "watery" or "moist" reputation may be partly due to the legend that they were metamorphosed into stars for immoderately bewailing the death of their brother Hyas, who had been killed in Libya by a wild boar.

The lower or left-hand corner of the "V" is marked by Aldebaran (in the fiery *right* eye of the enraged bull), and the upper or right-hand one by Epsilon (in the *left* eye), while Gamma (in the nose) marks the angle. Between Epsilon and Gamma in the northern or right-hand branch of the "V" are three fourth-magnitude stars, known as the Deltas, while between Aldebaran and Gamma are a pair of fourth-magnitude stars called the Thetas.

Aldebaran, or Alpha Tauri, the sturdy leader of the Hyades group, and the brightest star in the constellation, is a standard first-magnitude star, of a light-rose or rose-red colour, and is one of the most important heavenly bodies. To the Arabs, who gave the star its name Aldebaran—meaning the "Follower"—because it followed the Pleiades, it was also known as the "Eye of the Bull." Mrs. Sigourney, in *The Stars*, thus alludes to it:

> . . . Go forth at night,
> And talk with Aldebaran, where he flames
> In the cold forehead of the wintry sky.

It is a beautiful double, but is rather difficult for an instrument smaller than three-and-a-half-inch. The

companion star is found to be of the tenth magnitude and of a bluish colour.

Aldebaran is the fourteenth star in order of brightness in the entire heavens, and gives out about one hundred and sixty times as much light as the sun. Its spectrum shows it to be rather far advanced in physical development, though it is generally classed as belonging to the solar type of stars. About the last of September it appears in the early evening sky, and is visible thereafter at some hour of the night until near the end of May. It rises an hour after the misty little dipper of the Pleiades, and about two and a half hours after Capella, and burns bright

Like a fire in the field of night.

It requires seven hours to reach the meridian, when it is a little more than two-thirds of the way up from the horizon to the zenith. It rises when the sun sets at the beginning of December, and culminates at 9 P.M., January 10th. It lies along the moon's path, and is frequently occulted by that satellite. By reason of its position it is much used by navigators in reckoning longitude at sea. It was one of the four Royal Stars of astrology, and was considered a fortunate star, portending riches and honour. It is forty-five light years distant, has a proper or cross motion of eight miles a second, and is receding from the solar system at the rate of thirty-four miles a second.

About eleven degrees to the right or north-west of Aldebaran is a filmy, dipper-shaped little group of bluish stars—the sweet-voiced Pleiades—the vanguard of the winter starry host, and the most remarkable naked-eye group in the heavens. Appealing strongly to the imagination, and being visible from every inhab-

ited quarter of the globe, it has figured largely in the myth, legend, and literature of every age and race. From the time of Homer and Hesiod down to the present, poets innumerable have had their fancy roused by the wonder and mystery of this tiny cluster of twinkling stars, and have endeavoured to emphasise in some form its mystical beauty and its charm. It was observed and written of in China over four thousand years ago, and the early sacred records of Egypt allude to a time when it marked the position of the vernal equinox, as the great year of the Pleiades.

Among the many elegant metaphors inspired by the notable group is that of Bayard Taylor, who likened the cluster to "a swarm of golden bees," as also that of Tennyson, who beautifully describes it as "glittering like a swarm of fire-flies" in the evening's dusk. In Milton's description of the Creation in *Paradise Lost*, it is said of the sun that:

> . . . the grey
> Dawn and the Pleiades before him danc'd
> Shedding sweet influence.

The Pleiades (from the Greek πλέω, to sail) lie on the shoulder of the Bull, within four degrees of the ecliptic, and cover a space of a little more than three square degrees. Nine of the brightest stars bear the names of Atlas and his seven daughters, and their mother, the nymph Pleione. The six which are plainly visible to the average eye are Alcyone, Maia, Electra, Atlas, Merope, and Taygeta, while Celæno, Pleione, and Asterope hang on the verge of visibility. While many people can see seven, and moderately keen eyes count nine Pleiades, exceptionally keen-sighted star-gazers distinguish anywhere from eleven to fourteen.

Harvard College Observatory

PLATE XVI. The Little Dipper of the Pleiades

(View at culmination)

With an opera-glass, thirty more stars may be counted, and with a two-inch telescope about one hundred, while the photographic plate reveals nearly twenty-five hundred.

The principal stars, which are estimated to be almost as far apart as the distance from the earth to the nearest fixed star, form a rough outline of a short-handled dipper, called the "little dipper of the Pleiades." In Plate XVI., from a photograph taken by Pickering at Arequipa, Peru, the two larger stars to the left, are Atlas, a fourth-magnitude star at the end of the handle of the dipper, and Pleione, a star of about the fifth and a half magnitude, just above it. Situated at the junction of the handle with the bowl, is coy Alcyone, the peerless Pleiad, a star of the third magnitude, which some have been pleased to term the "lotus-flower of heaven."

An imaginary line running from between Atlas and Pleione, through Alcyone and onward, will pass through Electra, a fourth-magnitude star in the bottom of the dipper on the outside, and the second star in brightness in the cluster. South of this imaginary line is Merope, a fourth- and a third-magnitude star, in the bottom of the dipper toward the handle. North of the line is Taygeta, a fourth-and-a-half magnitude star on the farther side of the brim of the dipper. Between Taygeta and Alcyone, in the top of the brim, is the fourth-magnitude star Maia, while about half-way between Taygeta and Electra, on the farther side of the bowl, is Celæno, a star of about the fifth and a third magnitude. Asterope, the faintest star of the group, lies a short distance above and to the left of Taygeta, and is about of the seventh magnitude.

Atlas, Taygeta, and Asterope are double stars. The

two stars of Atlas are of the fourth and the fifth magnitude. Asterope's two stars are of about the seventh magnitude, and Taygeta's of the fourth and a half and the tenth magnitude.

Alcyone, or Eta Tauri, the "big sister" of the Pleiades, the brightest star in the cluster, is a triple star even in a two-inch telescope, its two smaller component stars being of the seventh magnitude, the three together forming a beautiful little triangle. In his *Alcyone*, Archbold Lampman describes it as

> the great and burning star,
> Immeasurably old, immeasurably far,
> Surging forth its silver flame
> Through eternity.

It is supposed to be sixty times more brilliant than Sirius, and is famous as being the star which the German astronomer Mädler, some sixty years ago, imagined to be the centre of revolution of the universe—the place of the Almighty, the Mansion of the Eternal! Mädler's fascinating theory, which was largely a revival of the old Hindu conception of the material universe, and was popular for a time, has, however, long since been rejected. Alcyone culminates at 9 P.M., December 31st. The star, Maia, has an invisible companion, detectable by the spectroscope.

The chief stars of the Pleiades are of the sirian type, and are drifting across the heavens in the same general direction. They are supposed to be about two hundred and fifty light years distant, and are receding from the solar system at the rate of twenty-five miles a second. The cluster is, by some, considered to be even larger than the Greater Bear. Modern photographs show the entire group to be completely enshrouded in a magnifi-

Yerkes Observatory

PLATE XVII. The Nebulosities of the Pleiades

(In these wonderful nebulosities several instances have been found of star and nebula radiating light of identical quality.)

cent tracery of nebulous matter (Plate XVII.), which stretches in curious wisps and streaks from star to star. From this wonderful mass of apparently intertwisted nebulæ, or "cosmical fog," which for ages may have been condensing into stars, a great system is possibly developing and is already in the last stages of its formation. Or again, it may be, as some astronomers have asserted, that what is seen is radiant matter ejected from these great and far-off orbs, just as rare gaseous matter is driven away from the sun to form its corona, but on an inconceivably more colossal scale.

To the Greeks, the Pleiades were the daughters of Atlas and Pleione, and nymphs of Diana's train, whom the gods placed among the stars, near their half-sisters, the Hyades. Their names are Alcyone, Electra, Maia, Merope, Taygeta, Asterope, and Celæno. Bryant in *The Constellations*, thus alludes to them:

> The group of sister stars, which mothers love
> To show their wondering babes, the gentle seven.

As the legend runs, they were placed in the sky along with their father and mother on account of their filial sorrow, when their father, who with the other Titans made war upon Jupiter, and being conquered, was condemned to bear forever the dome of heaven on his head and hands. Another fable relates that one day, when strolling through the forest, the seven nymphs were pursued by the hunter Orion, who was attracted by their great beauty, As they fled, they prayed in their distress to the gods for rescue, when just as Orion was about to overtake them, Jupiter, in pity, changed them into doves, and transferred them to the heavens.

The Pleiad sisters were all married to immortal gods save one, Merope, who was wedded with a mortal,

Sisyphus, King of Corinth, the light of whose star therefore grew dim. Some say her star was the "lost Pleiad," the classical story of which is of very ancient origin and well-nigh universal. Aratus, in the third century before the Christian era, thus wrote of the Pleiads:

> Their number seven, though the myths oft say,
> And poets feign, that one has passed away.

Electra's star is sometimes mentioned as the lost one, because, upon the burning of Troy, she veiled her face, in order not to behold the ruin of that city, which was founded by her son Dardanus.

Maia, the eldest of the Pleiades, and the most beautiful of the seven sisters, was the mother of Mercury by Jupiter. Taygeta was the mother of Lacedæmon, who was married to Sparta, the daughter of Eurotas, and who named his capital, the chief city of the Peloponnesus, after her. Celæno, who was beloved by Neptune, is reported to have been struck by lightning, and her star is regarded by some as the "lost Pleiad." Asterope was the wife of Œnomaus, a son of Mars, and was the mother of the beautiful maiden Hippodamia, one of whose suitors was Euryalus. Pleione, was the mother of the seven sisters, and her star, which the spectroscope reveals as variable, is believed by Pickering to be the true "lost Pleiad." It is now about twice as bright as it was fifty years ago. Then, too, according to some, the famous star that appears to have been lost, may have been a *Nova*, which has faded from view.

Biblical references to the group are found in Job xxxviii., 31, and Amos v., 8. The inquiry addressed by the Almighty to the patriarch Job, in a voice out

of the whirlwind, as rendered in the Revised Version reads:

Canst thou bind the cluster of the Pleiades,
Or loose the bands of Orion?

Amos, the herdsman of Tekoa, in his *Rhapsody of the Judgment to Come*, wrote:

> Seek Him that maketh the Pleiades and Orion,
> . . . . . the Lord is his name.

To the ancients, the heliacal rising of the Pleiades —the rising before daybreak—heralded the summer season, while their acronical rising—the rising at sunset—marked the beginning of winter. Then, too, this celebrated star-group served as a guide to the husbandman as to seedtime and harvest:

> When Atlas-born, the Pleiad stars arise
> Before the sun above the dawning skies,
> 'Tis time to reap; and when they sink below
> The morn-illumined west, 'tis time to sow.

Alluding to their showery nature, Pope, in his *Spring*, writes:

> For see, the gathering flocks to shelter tend,
> And from the Pleiads fruitful showers descend.

Referring to their invisibility when the sun is passing through Taurus, Hesiod writes:

> There is a time when forty days they lie
> And forty nights, concealed from human eye.

The Pleiades rise in the north-east, an hour before Aldebaran, and occupy seven hours and thirty minutes in reaching the meridian, when they are rather more than three-quarters of the way up from the horizon. Between nine and ten o'clock on Hallowe'en they are about half-way up from the horizon to the zenith. During the winter months they are seen high up in the evening sky, slowly advancing toward the western horizon. In March they set soon after nine o'clock and disappear from the evening sky in April.

At the midnight culmination on the 17th of November—the Pleiad month—memorial festivals have been observed from remote antiquity by many peoples in many lands. Usually these festivals are connected with some legend of a deluge, or other great calamity that overwhelmed mankind, in the far distant past, when the Pleiades were prominent in the sky. The Feast of Lanterns—a great national festival of Japan—is supposed to have been originally commemorative of some such event. Then, too, it is thought by some, that All Hallow Eve, All Saints' Day, and All Souls' Day, of the present calendar, are a survival of the three days memorial festival of the dead, almost universally observed in early times on the last day of October and the first two days in November, and in some way connected with the Pleiades. It has also been suggested that the "tors"—names given to British hilltops—were connected with the worship by the Druids of this little group of stars. As mentioned by Olcott, Arthur's Seat at Edinburgh may be regarded as a notable example of an old site formerly thus used.

Among the many Greek temples oriented to the "Seven Stars" was the celebrated Parthenon, on the Acropolis at Athens, one of the finest and most import-

ant edifices ever erected. It was built of Pentelic marble, in the Doric style, and was completed in the year 438 B.C. In the Euphrates region, the Pleiades and the Hyades were termed the Great Twins of the ecliptic, as Castor and Pollux were the Twins of the zodiac. The Arunta, one of the aboriginal Australian tribes, believe that, together with the sun and moon, the Pleiades were the heavenly ancestors of their race. Hesiod called them the "Seven Virgins," Virgil knew them as the "Virgin Stars" and Milton termed them the "seven Atlantic Sisters." The Spaniards called them "the seven nanny goats," while popularly they are known as the "clucking hen" or the "hen and chickens."

Besides Aldebaran and the two famous clusters, Taurus has several remarkable stars. Beta Tauri, or El Nath, a pure white star of the second magnitude, marks the tip of the northern horn of the Bull. It also indicates the place where the right foot of Auriga rests on the Bull's horn, being common to the two constellations. Zeta Tauri, a third-magnitude star, nine degrees below El Nath, marks the tip of the southern horn. The "golden horns" of the Bull, as Virgil describes them, are between fifteen and twenty degrees in length. About one degree north-west of Zeta, is the celebrated Crab Nebula (Plate XIV.), one of the most beautiful nebular objects in the heavens. It is an irregular, roundish mass of nebula, somewhat comet-like in appearance, and was the first nebula discovered by Messier. Unfortunately it is visible only in a very powerful instrument. The star Lambda is an Algol variable, changing from the third and a half magnitude to the fourth and a fifth magnitude in a period of three days, twenty-two hours, and fifty-two minutes.

Orion
(The Giant Hunter)

Situated in the most brilliant region in the heavens, south-east of Taurus, is the most interesting and beautiful constellation Orion, glorious alike to the eye and to the telescope. It is the richest and most impressive of all the constellations, and next to The Dipper is probably the most widely known of the stellar groups. It lies across the celestial equator, partly within the Milky Way, wholly south of the ecliptic, and is visible from all parts of the world. In Brown's *Primitive Constellations* it is shown, however, that about four thousand years ago it was situated, not on, but entirely below, the equator. It is one of the largest of the constellations, and is also one of the very few in which the natural grouping of the stars suggests the figure that has, from the earliest times, been connected with it. It is the one most frequently alluded to in literature, is mentioned in the books of Job and Amos, and also in the writings of Homer, Hesiod, and Virgil.

The constellation is easily recognised by an irregular quadrilateral, about eighteen degrees in its greatest length, formed by four brilliant stars, which mark the two shoulders and the two legs of the gigantic hunter, and by three bright stars which lie in an oblique line, in the middle of the quadrilateral, and form the giant's gemmed Belt. Manilius thus alludes to it:

> Near the Twins behold Orion rise.
> His arms extended measure half the skies;
> His stride no less. Onward with steady pace,
> He treads the boundless realms of starry space;
> On each broad shoulder a bright gem displayed,
> While three obliquely grace his mighty blade.

And Longfellow, in his *Occultation of Orion*, makes the following reference:

> Begirt with many a blazing star,
> Stood the great giant Algebar,
> Orion, hunter of the beast!
> His sword hung gleaming by his side,
> And on his arm, the lion's hide
> Scattered across the midnight air
> The golden radiance of its hair.

As Orion appears above the north-eastern horizon he is in a reclining posture, from which he slowly rises until he reaches the meridian, when he is in the upright position. As he approaches the western horizon his position becomes more and more inclined. Tennyson, in *Locksley Hall*, thus wrote:

> Many a night from yonder ivied casement, ere I went to rest,
> Did I look on great Orion sloping slowly to the west.

This magnificent constellation is the chief ornament of the frosty sky of winter, and is visible from late in October till May. Around New Year's Day it appears in the east at sunset, and is upright in the southern sky about nine o'clock in the evening in February. During the next two months it moves somewhat rapidly down the western sky, and disappears from evening view early in May. All told, Orion contains two stars of the first magnitude, four of the second, four of the third, three of the fourth, and over twenty of the fifth. Lying in a rich region of the heavens, it possesses a great number of stars of the sixth magnitude. It abounds in nebulous stars, and is wonderfully rich in telescopic objects. The spectra of its brighter stars,

with the exception of Betelgeux, indicate that they are in the earlier stages of stellar development.

The figure of Orion as represented in classical atlases of the heavens, is that of a colossal giant trampling on a timid hare, and facing in heroic attitude the mighty Bull, that, with glaring eye, is rushing down upon him with his long, golden horns, (Frontispiece). Over his left arm hangs a red lion's hide, that serves as a shield, and which he is shaking at the bull. With his uplifted right hand he swings a massive club, with which he is about to strike a blow at the forehead of the infuriated animal. From his dazzling belt or girdle, to which Sir Walter Scott, in the *Lay of the Last Minstrel*, refers, as "Orion's studded belt," dangles his famous sword or hunting knife. Bryant, in *The Constellations*, writes:

> I have seen
> The great Orion, with his jewelled belt,
> That large limbed warrior of the skies, go down
> Into the gloom.

According to Grecian legend, Orion was the son of Neptune and Euryale, and became the greatest hunter in the world. By Homer he was described as the "tallest and most beautiful man," and was so tall that he could wade the sea. By some he was identified with the great Nimrod, "the mighty hunter before the Lord." He profanely boasted that he was able to conquer any animal the earth could produce. Whereupon a gigantic scorpion rose out of the ground, at the command of Juno, and bit his foot, causing his death. Subsequently, at the request of Diana, he was placed among the stars, directly opposite the Scorpion, so

that he might never again be molested by the offensive reptile.

> And so 'tis said that, when the Scorpion comes,
> Orion flies to utmost end of earth.
>
> ARATUS.

Another legend relates that the giant Hunter was the companion of the Huntress Diana, who, notwithstanding her heart was supposed to be Cupid-proof, fell in love with him and would have married him, had not her jealous twin-brother Apollo opposed their union. The indignant brother persuaded her one day to try her skill at archery, by shooting at a certain object in the sea. She aimed a shaft and hit the shining mark, which proved to be the head of Orion, who, it is said, was amusing himself by wading at some distance from shore. Her arrow having killed him, Diana had him placed among the stars, where he shines to this day as the most gorgeous stellar figure in the entire sky.

Still another story asserts that Orion was the lover of Merope, daughter of Œnopion, King of Chios, by the nymph Helice. Having been of great service to the king, in clearing his country of wild beasts, he sued for Merope's hand in marriage. On being refused, he attempted to take her by force. Œnopion, enraged at this and other improper conduct, made him drunk, and, having put out his eyes, left him alone on the seashore. The blinded hero, following the sound of a Cyclop's hammer, went to Lemnos, and made his way to Vulcan's forge, where he besought assistance. Vulcan, taking pity on him, instructed Cedalion to be his guide, and Orion, placing him on his shoulders, proceeded eastward to the top of a mountain, where, facing the rising sun,

the healing beams restored his sight. Longfellow thus alludes to this episode:

> . . . . but he
> Reeled as of yore beside the sea,
> When blinded by Œnopion
> He sought the blacksmith at his forge,
> And climbing up the narrow gorge,
> Fixed his blank eyes upon the sun.

On account of its setting in the late autumn, Orion has always been regarded as a somewhat stormy constellation. Milton, in *Paradise Lost*, thus alludes to its boisterous character:

> When with fierce winds Orion armed
> Hath vexed the Red Sea coast.

The loss of the Roman fleet in the first Punic War was attributed by Polybius to its having sailed between the risings of Orion and Sirius. And Hesiod carefully warned all seafarers to beware the dangers of the sea, when the Pleiades flying from Orion are lost in the waves.

The two chief stars of the constellation are Betelgeux and Rigel, both first-magnitude stars, although Rigel is generally the brighter star. Betelgeux, or Alpha Orionis, which is the first of these to appear above the horizon, rises in the north-eastern sky about an hour and a half after Aldebaran. It marks the right shoulder of Orion, and is one of the most remarkable, irregularly variable, stars in the heavens. It is a spectroscopic binary, and its variability was detected by Sir John Herschel in 1836. In 1852 and 1894 and again in 1908 it outshone Rigel. It is an orange-red star, the tone seeming to deepen as the star becomes

more faint, which would indicate that it may be entering upon the earlier stages of extinction. It is one hundred and nine light years distant, has a proper or cross motion of about three miles a second, and is receding from the solar system at the rate of ten and a half miles a second. It is supposed to give out nearly five hundred times as much light as the sun. It occupies six hours and thirty-four minutes in reaching the meridian, when it is nearly two-thirds of the way up from the horizon. It culminates at 9 P.M., January 29th. In astrology, Betelgeux denoted military or civic honours, and is often called the "Martial Star."

Rigel, or Beta Orionis, the brightest star in the constellation, lies some sixteen degrees below Betelgeux, and rises about fifteen minutes after it. It is a beautiful, white, first-magnitude star, with a tinge of blue and marks the giant's left foot, which is raised as if climbing a steep ascent. It is young in the order of evolution, and ranks with Arcturus in point of brilliancy. It is a most famous double star, separable with a two and a half-inch telescope. The companion star to youthful Rigel is of the eighth magnitude, and of a bright sapphire-blue colour. Rigel rises in the southeast, and occupies five hours and thirty-three minutes in reaching the meridian, when it is within four degrees of being half-way up from the horizon to the zenith. It passes the meridian one minute after Capella, and sets nearly two hours earlier than Betelgeux. It is one of the most remote of the brighter stars, being about four hundred and fifty light years distant. It is receding from the solar system at the rate of fifteen miles a second. Its light-giving power is estimated as ten thousand times that of the sun. With Aldebaran and Betelgeux, it forms a large triangle, enclosing Bellatrix.

Bellatrix, or Gamma Orionis, marks the left shoulder of the giant, and is a second-magnitude star, of a pale yellow colour. It is the first of the principal stars to appear above the eastern horizon, being followed closely by Betelgeux. It is sometimes called the "Amazon Star," or the "Female Warrior." It is receding from the solar system at the rate of five miles a second. Astrologically considered, Bellatrix is connected with the fortune of women, those born under its influence being lucky and fluent.

Saiph, or Kappa Orionis, is a third-magnitude star, situated in the right knee, eight and a half degrees east of Rigel. Along with Betelgeux, Rigel, and Bellatrix, it forms a large, irregular parallelogram that serves to outline the constellation.

The three dazzling second-magnitude stars in the Belt, which is about three degrees in length, lie midway between Betelgeux and Rigel. They are situated at equal distance from each other, make a slanting line across the sky, and are supposed to be the stars referred to by Job as the "bands of Orion." They are named Delta or Mintaka, Epsilon or Alnilam, and Zeta or Alnitak. Tennyson in *The Princess*, Part Fifth, refers to them as,

> Those three stars of the airy Giant's zone,
> That glitter burnish'd by the frosty dark.

The three stars in the stately Belt stand in a right line and point up to the red Aldebaran and the Pleiades and down to the bright Sirius. The uppermost star, Mintaka, lies exactly on the celestial equator, which passes about half way between Rigel and Betelgeux. The three stars are sometimes referred to, as the "Rake," "Jacob's Rod," the "Three Kings," and the

golden "Yard." In mythology they represent the arrow, with which Diana killed Orion.

Mintaka, or Delta, is a wide double, the principal star being white in colour and of the second magnitude, while the companion star is of the seventh magnitude and of a violet hue. Alnilam, or Epsilon, the middle star in the belt, is a white star of the second magnitude, with a distant blue companion. It is said to be a very hot star, its temperature having been estimated at about forty-five thousand degrees Fahrenheit. Alnitak, or Zeta, the lowest star in the belt, is a remarkable triple. The principal star is of the second magnitude, and shines with a yellowish-white light. The fifth-magnitude companion is of a purple colour, while the tenth-magnitude companion is grey.

A short, curved row of stars, depending from the belt, and running obliquely towards Saiph, marks that famous, ghostly weapon, the so-called Sword of Orion. This row of stars is sometimes called the "Ell," because it is once and a quarter the length of the Yard, or belt. The lowermost star of the row is the third-magnitude triple star Iota. The middle star, Theta, is a sextuple star, and is of course notable, as four of its components, which can be seen in a two and a half-inch telescope, form an irregular quadrilateral known as the "Orion trapezium," and the star itself is enveloped in the Great Orion Nebula. Large instruments show in addition several fainter stars in the trapezium group.

In Tennyson's *Merlin and Vivien*, Merlin thus alludes to Theta:

> A single misty star,
> Which is the second in a line of stars
> That seem a sword beneath a belt of three,

I never gazed upon it but I dreamt
Of some vast charm concluded in that star
To make fame nothing.

Situated a short distance below Mintaka, at a right angle with the line of the belt, is Eta, a third-magnitude star, which marks the handle of the sword. Immediately south of Alnitak, the lowermost star of the belt, is the fine fourth-magnitude star, Sigma Orionis. It is a most remarkable multiple star, a quintuple and a coloured variable, and altogether a charming object.

The head of the mighty hunter is marked by a small triangle of faint stars, the brightest of which is Lambda, or Meissa, a triple star of a light yellow colour, and of about the third-and-a-half magnitude. The uplifted club, which stretches across the Milky Way almost to the feet of the Twins and the southern horn of the Bull, is marked by several fifth- and sixth-magnitude stars. Whilst, running upwards between Bellatrix and Aldebaran is a curved line of little stars, concave towards the giant's head, representing the lion's hide that Orion carries on his left arm as a shield, and which, as it rises in the east, affords the first glimpse of the approaching constellation.

On a clear night, when there is little or no moonlight, Theta, the middle star in the sword of Orion, is seen to be somewhat hazy to the unaided eye. This haziness is due to the presence of a great misty cloud of light known as the Great Nebula of Orion (Neb. 1179), the largest nebula known outside of the Milky Way, and the most marvellous object of its kind in the northern heavens. It has been sometimes called the "Fish-mouth nebula," because when viewed through a telescope, it is in shape something like a fish-mouth (Plate XVIII.). According to Barnard it "vaguely

Mount Wilson Solar Observatory

PLATE XVIII. The Great Nebula in Orion

(In viewing the plate the side to the reader's right should be held downward. Recent spectrographic measures of the radial velocities of the gases in different parts of this vast nebula have—as pointed out by Aitken, in *The Adolfo Stahl Lectures in Astronomy*—shown that they were moving with different velocities, "in some parts receding relatively, in other parts approaching," and have led astronomers to believe that the entire intensely hot and incandescent mass is by no means in a quiescent state.)

resembles a ghostly bat flitting through the night of space." It is one of the two or three nebulæ that are bright enough to be visible to the naked eye. It can be plainly seen with an opera-glass, and a prism binocular shows it well. In a two-inch telescope it is seen to greater advantage, and in still larger instruments is a most wonderful object. It was discovered by Cysat of Lucerne, in 1618, but was first really described and sketched by Huyghens in 1656. It is a "green" nebula, and yields a bright line spectrum, characteristics of the lighter gases such as hydrogen and helium. It also displays the characteristic green ray, which marks the unknown element named "nebulium."

It is a widely diffused and irregular nebula composed largely of glowing gases, but having, as shown by Wolf, outlying spiral branches. It is part of a vast nebulous system enveloping nearly the entire constellation, covering an area thousands of times larger than Neptune's huge orbit. The densest part of the nebula—that immediately above the "trapezium"—presents a somewhat curdled appearance, indicative of the formation of various centres of condensation, of which the final result will be a group of stars. There are, as Serviss says, in his eloquent way: "stars apparently completed, shining like gems just dropped from the hand of the polisher, and around them are masses, eddies, currents, and swirls of nebulous matter yet to be condensed, compacted and constructed, into suns." In the language of Tennyson here are

Regions of lucid matter taking form,
Brushes of fire, hazy gleams,
Clusters and beds of worlds, and bee-like swarms
Of suns and starry streams.

According to W. H. Pickering this magnificent nebula is not less than one thousand light years distant. Hence the observer sees it, not as it is now, but as it was more than a hundred and fifty years before the Norman Conquest. It is receding from the solar system at the rate of about eleven miles a second.

CHAPTER VI

THE NIGHT-SKY OF WINTER—(*Continued*)

Auriga

(The Charioteer)

DIRECTLY east of Perseus, between Taurus and the Lynx, is Auriga, the Charioteer or the Waggoner. It is a very ancient and widely extended constellation, and is largely involved in the Milky Way. It is an irregular, five-sided figure, somewhat resembling a shield, and measures some forty degrees from east to west, and about thirty degrees from north to south. It is easily recognised, as its chief feature is a brilliant, first-magnitude star of pearly lustre, with no other star in its neighbourhood comparable to it in brightness. Then too, an imaginary line drawn from the Dragon's Head across the pole star leads to it. And again, a line connecting Dubhe, the upper front star of The Dipper, with its outlying stars, will, if prolonged, pass through the constellation.

It has been represented on celestial maps by the figure of a man seated on the Milky Way, and resting one foot upon the right horn of the Bull, with a goat on his shoulder, her two kids in his left hand, and a long whip in his right. Capella, the Goat-star, shines in the heart of the imaginary goat, while near-by is a

tiny, sharp-pointed triangle, formed by three fourth-magnitude stars called the Kids.

Auriga is fabled by the Greeks as representing Erechthonius, son of Vulcan and Atthis, the daughter of Cranaus, King of Attica, who was deformed, and was reared by Minerva without the knowledge of the other gods. When he had grown up, he expelled Amphictyon, and became the fourth king of Athens, and is said to have invented the four-horse chariot, for which he was rewarded by Jupiter with a place in the sky. Manilius thus refers to the constellation:

> Close by the kneeling Bull behold
> The Charioteer, who gained by skill of old
> His name and heaven, as first his steeds he drove
> With flying wheels, seen and installed by Jove.

The leading star of the constellation, Capella, or Alpha Aurigæ, lies near the northern edge of the Milky Way, about half-way between Bellatrix and the pole star. It is situated in the heart of the goat, or rather near the left or western shoulder of the charioteer, and is one of the brightest stars in the northern skies, and is nearer the pole than any other first- or zero-magnitude star. It is a brilliant, creamy-white star, brighter than the first magnitude, and belongs to the solar type, being at about the same stage of development as the sun.

It is a hot and rarefied body of immense magnitude, about forty times rarer than the sun, and gives out about 120 times more light. According to J. E. Gore, it is estimated to be about fourteen million miles in diameter.

It is a spectroscopic binary, one of those stars which the spectroscope shows to be attended by an invisible companion of enormous mass. Its period of revolution

is 104 days, the principal and companion stars being of nearly equal size. It is forty-nine and a half light years distant, has a proper or cross motion of nineteen-and-a-half miles a second, and is receding from the solar system at the rate of eighteen-and-a-half miles a second.

Capella rises almost exactly in the north-east, and occupies ten hours and seventeen minutes in reaching the meridian, which it passes at some distance north of the zenith. During August evenings it rises about ten o'clock, and at sunset about the middle of October. It culminates at 9 P.M. on January 19th. It is above the horizon over twenty hours out of the twenty-four, rising again in three hours and twenty-six minutes after it sets. It presides over the stars of winter, and is visible every night in the year in some part of its course. July is the only month when it is not visible at some time before midnight.

Capella was termed by the Arabs the "Guardian of the Pleiades," and by the English poets it was called the "Shepherd's Star." By ancient mariners the rainy Goat-star and the Kids were accredited with exerting a direful influence. Alluding to their stormy nature, Aratus wrote:

> Capella's course admiring landsmen trace,
> But sailors hate her inconspicuous face.

In like vein the celebrated Alexandrine poet, Callimachus, in the third century B.C., wrote in an epigram of the Anthologia:

> Tempt not the winds, forewarned of dangers nigh,
> When the Kids glitter in the western sky.

With astrologers Capella portended civic and military honours and wealth.

Menkalina, or Beta Aurigæ, the second star in the constellation, is a bluish-white star of the second magnitude, on the right shoulder of the charioteer, about ten degrees east of Capella. It passes the meridian some six degrees from the zenith, about forty-three minutes after the latter star. Like Capella, it is a spectroscopic binary, its component stars being about seven-and-a-half million miles apart. E. C. Pickering, in 1869, calculated the period of revolution to be four days, and the relative velocity as one hundred and fifty miles a second. It has resolved itself on further observation by means of the spectroscope into a quaternary system. It was one of the first spectroscopic binaries to be discovered, and is receding from the solar system at the rate of seventeen miles a second.

El Nath—Gamma Aurigæ or Beta Tauri—is a white, second-magnitude star, common to the constellations Auriga and Taurus, and marks the place where the right foot of the charioteer rests upon the tip of the right horn of the Bull. Aratus thus refers to it:

> The tip of the left horn and the right foot
> Of the Charioteer, one star embraces.

Iota, a third-magnitude star, about ten degrees northwest of El Nath, is in the left foot. Three fourth-magnitude stars, Epsilon, Zeta, and Eta, which form a small isosceles triangle a short distance below and to the west of Capella, represent the Kids. Theta, a third-magnitude star, about nine degrees south of Menkalina, marks the charioteer's right hand, resting upon his right knee and holding a long whip represented by several fifth- and sixth-magnitude stars. Delta, a fourth-magnitude star, about nine degrees north of

the shoulder stars, together with Xi, a fifth-magnitude star, indicates the charioteer's head. Along with Capella and Menkalina, it forms an approach to an equilateral triangle.

The now historic Nova—Nova Aurigæ—discovered on January 23, 1892, by Dr. T. D. Anderson of Edinburgh, a famous observer of variable stars, appeared in proximity to the southern border of Auriga, about two degrees north-east of El Nath. Its image was afterwards found on photographic plates taken in December at Harvard College Observatory. At its greatest brightness, it was of about the fourth magnitude. In three months it had dwindled to the twelfth magnitude, but brightened during August to the ninth magnitude, after which it gradually faded away.

Lynx
(The Lynx)

Lying above Gemini, and between the head of Ursa Major and that of Auriga, is the rather extensive but inconspicuous constellation known as the Lynx or the Tiger. It is one of Hevelius's constellations, and dates only from the seventeenth century. To the naked eye it offers no attraction, having only one star brighter than the fourth magnitude. It has no legendary or mythological history, but is interesting on account of the number and beauty of its double and triple stars. The star 12 Lyncis, in the eye of the animal, is a fine triple, the principal star being of the fifth magnitude, and the companion stars of the sixth and seventh.

Eridanus
(The Sky-River)

South of Taurus, between Orion and Cetus, is the great sky-river, Eridanus, the River Po. It is a large,

Alpha Leporis, or Arneb, the upper right-hand star of the trapezium, is the brightest of the four, and is near the centre of the asterism. It is a double star, of a pale-yellow colour, with a ninth-magnitude star of a grey colour. It culminates at 9 P.M., January 24th. Beta Leporis, or Nihal, is a rather difficult triple star except in the larger instruments, the two smaller components being of the tenth and eleventh magnitudes. The star Gamma is a wide double, separable even by a good opera-glass. The principal star is yellow and of the fourth magnitude, while the companion star is of the sixth-and-a-half magnitude, and of a pale-green colour. About four degrees south of Rigel are four small stars of the fifth and sixth magnitudes, which indicate the ears of the Hare. Eta, a fourth-magnitude star, is in the tail, while Zeta, also a fourth-magnitude star, is situated in the back, about five degrees south of Saiph.

The most remarkable object in the constellation is the crimson star R Leporis, which can be seen with an opera-glass. It is situated near the western border of the constellation, about three degrees west of Mu, a fourth-magnitude star in the eye of the imaginary hare. It was discovered by Hind in 1845, and is frequently referred to as "Hind's Crimson Star." It is a notable variable, with a period of 436 days, and ranges in brilliancy from the sixth to the ninth and a half magnitude. When at its brightest it is of a coppery-red colour, but when faintest it is of a deep blood-red.

Columba
(Noah's Dove)

Under Lepus, and south-west of the Greater Dog, is the small constellation of Columba, the Dove. The

figure heads to the south-east, and is supposed to represent the dove that Noah sent out from the ark. Besides its chief star, Alpha Columbæ, or Phaet, which is of about the second and a half magnitude, it contains one star, Beta, of the third magnitude, and two, Epsilon and Gamma, of the fourth, as also a number of smaller stars. Phaet is easily identified, as a line connecting Procyon and Sirius will, if produced twenty-three degrees, point to it. According to Lockyer, the Egyptian temples at Edfu and Philæ, along with several others, were oriented to Phaet.

Phaet culminates at 9 P.M., January 26th.

Canis Major
(The Greater Dog)

Canis Major, the Greater Dog, lies south-east of Orion, on the western border of the Milky Way, and is remarkable because it contains Sirius, the blazing Dog Star, the brightest star in all the sky. It is not a large constellation, but has, in addition to its magnificent leader, three stars of the second magnitude, three of the third, and a number of the fourth, fifth, and sixth magnitudes.

According to Greek fable, Canis Major was one of the hounds of Orion, which accompanied the great hunter when he was translated to the sky. Another legend asserts that it represents the dog given by Aurora to Cephalus, which surpassed all rivals in fleetness. To the Egyptians it was the representative of their deity Anubis, which had the figure of a man with the head of a dog. They regarded it, when appearing in the east just before sunrise, as the herald of the annual inundation of the Nile. Anubis was the guard and companion of Isis, wife of Osiris, the god of

the Nile, and in Egyptian temples was represented as the guard of other gods.

On celestial maps the Dog is generally figured as standing on his hind feet, facing his master Orion, with, as Young intimates, an eye out for the Hare, which cowers beneath the hunter's feet.

The chief star of the constellation is the dazzling Sirius, a star of surpassing brilliance, Sirius the Superb.

> Hail, Mighty Sirius, monarch of the Suns!
>
> LYDIA H. SIGOURNEY, *The Stars.*

This famous star is situated about sixteen-and-a-half degrees south of the celestial equator, nearly in line with the three stars in the belt of Orion. It enters the evening sky just as the bright summer star Vega is leaving it, and is visible from every habitable quarter of the globe. It blazes in the wide-stretched jaws of the imaginary dog, and was called by the ancients the Dog Star, on account of its association with the *Dies canicularis*, or Dog Day—the "dog days" being reckoned from its heliacal rising. Popularly, the "dog days" are the sultry, close part of the summer, a period in July and August, when canine madness is supposed to be prevalent.

Sirius is alluded to as the Dog Star in Homer's *Iliad*, Book XXII. (Lord Derby's tr.), thus:

> Th' autumnal star, whose brilliant ray
> Shines eminent amid the depth of night,
> Whom men the dog-star of Orion call.

Serviss mentions that from its proper or cross motion in the heavens, it has been calculated that, six hundred centuries ago, Sirius was on the *eastern* border of the

Milky Way. It moves, during a century, through a space on the celestial sphere equivalent to about one-fourteenth the apparent diameter of the moon. According to a fable related by the Persian astronomer, Al Sufi, the stars, Sirius and Procyon, were the sisters of Canopus. Canopus married the star Rigel, but, having murdered her, he fled towards the south pole, fearing the anger of his sisters. Sirius, it is related, followed him across the Milky Way.

In her *Poems of Progress*, Ella Wheeler Wilcox thus writes:

Since Sirius crossed the Milky Way
  Full sixty thousand years have gone,
Yet hour by hour, and day by day,
  This tireless star speeds on and on.

On planets old ere form or place
  Was lent to earth, may dwell—who knows—
A God-like and perfected race
  That hails great Sirius as he goes.

Since Sirius crossed the Milky Way
  Full sixty thousand years have gone,
No mortal man may bid him stay,
  No mortal man may speed him on.

No mortal mind may comprehend
  What is beyond, what was before;
To God be glory without end,
  Let man be humble and adore.

The radiant Sirius is a brilliantly white star with a tinge of blue or green, and its official magnitude, —1.6, rates it as the most splendid of all the stars. Its

spectrum shows that it is in a relatively early stage of solar evolution, and is enveloped in a dense atmosphere of hydrogen gas. It is about thirty times as luminous as the sun, and has about ten times the brilliancy of either Aldebaran or Altair, and about one-ninth that of the planet Venus when at its greatest. It is the nearest of the stars visible to the unaided eye in northern latitudes, and is the brightest of the so-called sirian stars. To its relative nearness, it owes in part its apparent supremacy, as it is by no means the largest sun in the universe. Rigel, Canopus, and Betelgeux far exceed it in actual luminosity. The late Finnish poet, Zakris Topelius, fancifully accounted for the exceptional magnitude of Sirius by stating that the lovers, Zulamith the Bold and Salami the Fair, after a thousand years of separation and toil, while building their bridge of starry light, the Milky Way, upon meeting at its completion,

> Straight rushed into each other's arms,
> And melted into one.
> So they became the brightest star
> In heaven's high arch that dwelt,
> Great Sirius, the mighty Sun,
> Beneath Orion's belt.

The colour of Sirius, like that of some of the other brighter stars, varies with its altitude. Its momentary red flashes, seen when near the horizon, and doubtless due to the irregular dispersion of its light through tremulous atmosphere, seem to die out near the meridian. Miss Proctor, looking at it one evening in a six-inch telescope, as it emerged from below the south-eastern horizon, described it as flashing with all the colours of the rainbow:

First the flaming red
Sprang vivid forth; the tawny orange next;
And next delicious yellow; by whose side
Fell the kind beams of all-refreshing green.
Then the pure blue, that swells autumnal skies,
Ethereal played.

Tennyson, in *The Princess*, Part Fifth, thus alludes to it:

The fiery Sirius alters hue
And bickers into red and emerald.

On account of its super-brilliance, it has, more than once, been mistaken for a planet.

Sirius is one of the very noteworthy binaries. Its duplicity was detected by Alvan Graham Clark, the famous telescope-maker of Cambridgeport, Mass., on January 31, 1862. The companion star is a dull yellow star about ten seconds of arc distant from its principal, and nearly half as massive. It is of only the ninth and a half magnitude, and is invisible except in the largest telescopes. It is believed to be approaching the stage in which its light will practically die out. The two stars revolve around their common centre of gravity, in a period of about fifty-three years, in an orbit some twenty times wider than that of the earth around the sun. In his *Romance of Micromegas* (1752), Voltaire makes mention of an imaginary planet circling around Sirius, that was supposed to be over twenty-one million times larger in circumference than the earth, the inhabitants of which were proportionately tall (twenty miles) and proportionately long-lived.

Sirius has a diameter estimated at about fifteen times that of the sun, and pours forth more than twenty times

as much light. With Betelgeux and Procyon it forms a large equilateral triangle, notable for containing within its borders no star above the third magnitude. Among the several Egyptian temples oriented to it was that of Isis at Denderah. In classic days, it was regarded as a star of ill omen, whose "burning breath," according to Homer,

> Taints the red air with fevers, plagues, and death.

Sirius rises in the south-east, and takes five hours and three minutes to reach the meridian, when it is about one-third of the way up from the horizon. Hence it is above the horizon only a little over ten hours out of the twenty-four. It is the most southern of the brilliant winter stars, and appears in the evening sky about the middle of November, being the last one to return. On Thanksgiving evening, it rises about nine o'clock, and on Christmas evening shortly after seven. It comes to the meridian at 9 P.M. February 11th. It shines brightly in the south-west in the early evening in April, and retires from view about the middle of May. It is eight and three-fourths light years distant, has a proper or cross motion of ten and a third miles a second, and is approaching the solar system at the rate of five miles a second.

About six degrees to the right of Sirius, is Beta, or Mirzam, the second star of the constellation. It is a star of about the second magnitude, and is at the extremity of the dog's uplifted left paw. It passes the meridian twenty-two minutes before Sirius, and at about the same height. Some fifteen degrees south-east of Sirius are Delta, or Wezen, and Epsilon, or Adara, two second-magnitude stars, in the right flank of the dog. Epsilon is an orange-coloured star, with a ninth-

magnitude companion of a violet hue. It passes the meridian about fourteen minutes after Sirius, about one-fourth of the way up from the horizon.

Eta, or Aludra, in the tail, and Zeta, or Furud, in the left hind paw, are both of the third magnitude. The latter forms with Mirzam, Sirius, and Adara a trapezium, which is almost a rectangle. Nearly in line with Sirius and Mirzam is Gamma, or Muliphen. It is a fourth-magnitude star in the neck of the dog, and is a variable. About four degrees south of Sirius, is the star-cluster 1454. Its stars appear to be arranged in curves, and in the centre is a ruddy star.

Canis Minor
(The Lesser Dog)

Canis Minor, the Lesser Dog, lies south of Gemini, and north-east of Canis Major, on the other side of the Milky Way from Orion. It is a small but ancient constellation, about fifteen degrees in length, and contains only one star of the first magnitude, one of the third, and five of about the fifth. It owes its prominence to its lucida, Procyon, one of the most interesting stars in the sky.

According to Greek fable, the Lesser Dog was one of the other faithful dogs of Orion. Another legend asserts that it was one of Actæon's fifty hounds, that devoured their master, after Diana, whom he had seen bathing with her nymphs in the vale of Gargaphia, had transformed him into a stag, to prevent, as she said, his betraying her. It has also been regarded as Helen's favourite, that was lost in the Euripus. The Latins called it "Antecanis," the star before the Dog.

Alpha Canis Minoris, also known as Procyon, because it heralds the approach of the Greater Dog, is a

beautiful yellowish-white star of the first magnitude. Aratus thus alludes to it:

The dog's precursor, too, shines bright beneath the Twins.

Procyon is a rapidly-scintillating star, and is the only one out of the beautiful group of winter stars that is lightly tinged with yellow. It is situated in the hind quarter of the Lesser Dog, and is one of the nearest of the brighter stars. It is almost equidistant from Betelgeux and Sirius, and forms with them an equilateral triangle, across which flows the Milky Way. It has a faint, twelfth-magnitude companion, of a yellowish hue, discovered by Schaeberle at the Lick Observatory in 1896, which revolves around it in a period of about forty years. Some observations, however, lend support to the belief that the companion may be a small nebula rather than a star.

In order of stellar evolution, Procyon is about midway between Sirius and the sun. It is estimated that it gives out about eight times as much light as the latter orb. Horace in his ode to Mæcenas, wrote of it:

Jam Procyon furit.

which Mr. Gladstone rendered:

The heavens are hot with Procyon's rays.

In astrology Procyon portended good fortune and wealth.

Procyon rises a little north of east, and occupies six hours and twenty-one minutes in reaching the meridian, when it is about three-fifths of the way up from the horizon to the zenith. It appears above the horizon some twenty minutes before Sirius, and sets between

two and three hours after it. It rises when the sun sets about January 23d, and comes to the meridian at 9 P.M. February 24th. It is ten light years distant, has a proper or cross motion of eleven and a third miles a second, and is approaching the solar system at the rate of two and a half miles a second. About five degrees from Procyon, in an oblique line towards Gemini, is the white third-magnitude star, Beta. It is sometimes called Gomeisa, and is situated in the neck of the Lesser Dog.

Monoceros
(The Unicorn)

Lying between Orion and the two Dogs is the large but inconspicuous constellation Monoceros, the Unicorn. It was familiar to the Persians, and was known in early times as the Horse. The constellation extends about forty degrees from east to west, and is singularly barren of bright stars, having but four as bright as the fourth magnitude. It contains, however, a number of fine, small star-clusters, some of which are good objects, even for an opera-glass or prism binocular.

Gemini
(The Twins)

The third sign and fourth constellation of the zodiac, Gemini, the Twins, is a highly interesting and important constellation lying north-east of Taurus and west of Cancer. It is readily recognised by its two chief stars, Castor and Pollux, sometimes called by the old English people, "the Giant's Eyes"—the eyes of the giant Daze. Two remarkable parallel rows of stars, one leading from the head to the foot of Castor, the other leading from the head to the foot of Pollux, also help

to identify it. On most celestial maps the charming Twins are represented as two sturdy youths, standing side by side in the Milky Way, watching the conflict between Orion and the Bull (Frontispiece), each wearing, as Mrs. Martin aptly puts it, a bright star, as a sort of monocle, in the outer eye. Manilius thus refers to them:

> Tender Gemini in strict embrace
> Stand clos'd and smiling in each other's face.

Instead of twin brothers the Orientals, however, occasionally adopted two kids, and the Arabs two peacocks. The Latin title Gemini by which this noted star-group is now known dates only from early classic days.

The constellation is the highest in the zodiac, and can be seen from October to early June. The sun passes through it from June 18th to July 18th, when it is of course invisible. About six months later it is on the meridian at midnight. Altogether, Gemini contains one star of near the first magnitude, two of about the second, three of about the third, and a number of the fourth, fifth, and sixth magnitudes.

In astrology Gemini is of the House of Mercury. It is a masculine sign and fortunate. Its natives—those born from May 20th to June 21st—are said to be ruled by it.

Alpha Geminorum, or Castor, the most northerly of the two leading stars of the constellation, is a well-known double star, in the head of the twin named Castor, and is noted as being one of the first stars demonstrated to be of a binary character. Its duplicity was discovered by G. D. Cassini in 1678. It is the brightest and most beautiful double in the northern skies, and is the best object of its class for a small

telescope. The principal star is white with a slightly greenish tinge, and of about the second magnitude, while the companion star is approximately of the third magnitude, and also of a greenish-white hue. The two components are only four seconds of arc apart, and cannot be separated without the aid of a two-inch telescope. The period of revolution is estimated at three hundred and forty-seven years. Then, too, both components are themselves spectroscopic binaries, the fainter component having a tiny satellite revolving around it in a period of about three days, and the brighter component, one with a period of about nine days. Both the main components of Castor belong to the sirian type of stars, that large class which includes about half of all the stars in the sky. It was from observation of this pair of stars that Sir Wm. Herschel arrived at the knowledge of the physical connection of the double stars. Castor is about one hundred and sixteen light years distant, has a proper or cross motion of twenty-one miles a second, and is receding from the solar system at the rate of nearly four miles a second.

About four and a half degrees to the left of Castor is Beta Geminorum or Pollux, a slightly orange-tinted star, of rather less than the first magnitude. It is in the head of the twin named Pollux, and is now a brighter star than Castor, although about three centuries ago the latter was the lucida of the constellation. An imaginary line drawn through Rigel and Betelgeux points directly to it. Like Capella and the sun, Pollux belongs to the solar type of stars. It is a multiple star of at least six components, most of them too faint for easy observation. It is fifty-one light years distant, has a proper or cross motion of twenty-eight and a half

miles a second, and is receding from the solar system at the rate of two miles a second. It is one of the stars from which the moon's distance is calculated. In astrology Pollux was a fortunate star, portending eminence and renown.

The twin stars rise in the north-east, Castor occupying eight hours and fifteen minutes, and Pollux seven hours and fifty-three minutes, in reaching the meridian, when the former is nine-tenths and the latter seven-eighths of the way up from the horizon to the zenith. They become a familiar feature in the early evening sky in November, and about January 1st rise at the time the sun sets. They culminate at 9 P.M. February 24th, Castor passing the meridian about eleven minutes before Pollux. They are about the last of the radiant winter stars to leave the western sky, and are particularly attractive during the evenings of May and early June. Owen Meredith, in *The Wanderer*, thus refers to them:

The lone Ledæan lights from yon enchanted air
Look down upon my spirit, like a spirit's eyes that love me.

After the two leading stars, the brightest star in the constellation is Gamma, or Alhena, a star of about the second and a half magnitude, in the left foot of Pollux. Delta, or Wasat, is a yellowish third-magnitude double star, in Pollux's right arm, and Zeta, or Mekbuda, is a third-magnitude double star, and a variable, in his right thigh. Zeta is a bright yellow star, with a bluish companion of the seventh magnitude. The principal star varies its light, from about the third to about the fourth magnitude, in a period of ten days, three hours, and forty-three minutes. Theta, a third-magnitude star, is in the outstretched left hand of Castor, and

Epsilon, or Mebusta, a white, third-magnitude double star, is in his left thigh. The two third-magnitude stars Eta, or Propus, and Mu, or Tejat, mark Castor's left foot and ankle. Eta belongs to the long-period variables, and is noted as marking the locality where Sir William Herschel discovered the planet Uranus, on the 13th of March, 1781. The period of its variation occupies about two hundred and thirty-one and a half days, and its brightness varies between the third and fourth magnitudes.

A little west of Mu is a fifth-magnitude star, which marks the location of the summer solstice—the point where the sun appears to be, when it is farthest north of the equator, on June 21st.

About two degrees north-west of Eta is a splendid star-cluster, 35 M, which can be seen with a good opera-glass, and is just visible to the naked eye on a clear moonless night. It is beautiful even in a field-glass or prism binocular, and is a fascinating sight in a small telescope. On March 12, 1912, a new star, called Enebo's Nova, blazed out in Gemini, about two degrees south of Theta. It was discovered by Sigurd Enebo, an observer of variables, at Dombas, Norway. It was of a creamy-white colour, and of about the fourth magnitude, and was easily visible to the naked eye. The discovery was confirmed by two photographs taken at Harvard Observatory on March 11th. Its brightness fluctuated markedly, though on the whole it diminished rapidly, and its hue deepened accordingly. Dark lines of uranium and radium emanation have been found in its spectrum.

The mythological history of Gemini, the Twins, is not without interest. The constellation is regarded as representing the twin brothers Castor and Pollux,

famous knights of antiquity who were paid divine honours both in Sparta and Rome. According to Homer, they were the sons of Leda and Tyndarus, King of Lacedæmon, and consequently brothers of Helen of Trojan fame. Other tradition relates that they were doughty sons of Jupiter and Leda, "so famed for love," as Cowley writes. They were the Damon and Pythias, the Pylades and Orestes of the sky, and were said to have been born at the same time with their sister Helen, out of an egg. Yet another legend asserts that Pollux and Helen only were children of Jupiter, and that Castor was the son of Tyndarus. Hence Pollux was immortal, while Castor, like every other human, was mortal. Castor excelled in equestrian exercises and the management of horses, while Pollux was renowned for his bravery with arms, and for boxing. They took part in the hunt of the Calydonian boar, and accompanied the Argonauts in quest of the Golden Fleece.

> Fair Leda's twins, in time to stars decreed.

In the celebrated fight between the twin brothers and the sons of Aphareus, Castor was mortally wounded by Idas, but Pollux slew Lynceus, and Jupiter killed Idas with a flash of lightning. Whereupon, Pollux being inconsolable at the death of Castor, Jupiter, desiring to immortalise such proof of fraternal love, offered either to take him up to Olympus, or let him share his immortality with his brother. Pollux, it is said, preferred the latter, and so the brothers spend alternate days on Mount Olympus and in Pluto's realm. As Virgil aptly puts it:

> Pollux offering his alternate life,
> Could free his brother, and could daily go
> By turns aloft, by turns descend below.

They were looked upon by the ancients as the friends and protectors of navigation, and were often represented in the carved figureheads of ships. The balls of electric flame seen at the masthead and the yard-arm, in stormy weather, and known as "Ledæan lights," or "St. Elmo's lamps," were named in honour of them. It will be remembered that St. Paul, after the eventful voyage that had ended in shipwreck on the island of Melita, sailed from there to Puteoli, "in a ship of Alexandria," "whose sign was Castor and Pollux" (Acts xxviii., 11), and naturally had a safe voyage to Rome.

The Twins are usually represented in works of art as two youthful horsemen, with egg-shaped helmets crowned with stars, and with spears in their hands. The old Romans often swore by them, and later the name of the constellation itself came to be used in the same way.

A superstition prevailed among the Romans, and other nations, that Castor and Pollux often took part in their hard-fought battles, and led their troops to victory. Whenever they appeared, they were seen clad in rare armour, riding side by side, on magnificent snow-white steeds. It is said that at the great battle on the banks of Lake Regillus (B.C. 496), the Heavenly Twins suddenly appeared, armed and mounted, to aid the hard-pressed Romans in their desperate fight with the Etruscans, and afterwards carried the news of victory to the city. A temple (Plate XIX.) was subsequently erected to them in the Forum, on the very spot where they had been seen after the battle, opposite the famous Temple of Vesta, by order of the dictator Albinus, and was later consecrated on the Ides of Quintilis, July 15th, 480 B.C., the anniversary of the

battle. The temple was usually called that of Castor only, and was rebuilt more than once. The few fragments now remaining, consisting of three Corinthian columns with a very rich entablature, are of the finest Pentelic marble, and belong to the temple as it was restored by Tiberius in 6 A.D. Concerning these columns, careful antiquarians like Middleton say they are perhaps the most beautiful architectural fragments in Rome.

Macaulay, in his stirring poem, *The Battle of the Lake Regillus*, most fittingly celebrates the two youthful warriors, as he makes Sergius the High Pontiff say:

The Gods who live for ever
  Have fought for Rome to-day!
These be the Great Twin Brethren
  To whom the Dorians pray.

Back comes the Chief in triumph,
  Who, in the hour of fight,
Hath seen the Great Twin Brethren
  In harness on his right.

Safe comes the ship to haven
  Through billows and through gales,
If once the Great Twin Brethren
  Sit shining on the sails.

Wherefore they washed their horses
  In Vesta's holy well,[1]
Wherefore they rode to Vesta's door,
  I know, but may not tell.

Here, hard by Vesta's temple,
  Build we a stately dome
Unto the great Twin Brethren
  Who fought so well for Rome.

[1] *Lacus Juturnæ*—a spring that belonged, it is said, to the nymph Juturna, the waters of which were believed to bring healing to mankind.

Anderson

PLATE XIX. The Three Columns of the Temple of Castor and Pollux at Rome

CHAPTER VII

THE MILKY WAY—VARIABLE AND TEMPORARY STARS

Heaven's broad causeway paved with stars.
WORDSWORTH, *Dion*, Sec. IV.

A MOST conspicuous and wonderful feature of the night-sky, in the absence of moonlight, is the broad, irregular band of diffused, softly glowing, misty light, encircling the whole star-sphere, known as the Galaxy, or the Milky Way—La Voie Lactée. This great luminous belt, which has attracted special attention in all ages, consists of aggregations of enormously distant, faint stars, disposed in vast sparkling clouds, swarms, clusters, and streams, intermingled often with immense areas of green nebulous matter which serve as a luminous background to the stars themselves. It is regarded as the fundamental reference plane of the entire universe, as the equator is of the earth, and is quaintly referred to by Henry Vaughan in *Sun-Days*, as

The Milky Way chalk't out with Suns.

As the Milky Way is approached, the stars increase gradually in number, and are closer together in this region than elsewhere in the universe. In or close along its course, the outlines of which are roughly indicated on the charts, are to be found the majority of the first-magnitude stars, and generally, it may be said, the

passes over the club of Orion, through Monoceros, and over the head of Canis Major, to the prow of the ship Argo. On leaving Argo it goes through Charles's Oak, the lower part of the Southern Cross, and the feet of the Centaur. Here it is divided into two branches, the larger and brighter one passing through the celestial Altar, the tail of the Scorpion, the bow of Sagittarius, and Sobieski's Shield.

Crossing the equinoctial on its way north, it winds over the feet of Antinoüs into Aquila, through Sagitta and up to Cygnus, where it involves the entire figure of the so-called Northern Cross. Thence it crosses a part of Cepheus, and passes on to Cassiopeia, where the tracing began. The other branch crosses below the heart of the Scorpion, and is eventually lost in the borders of Ophiuchus, though a great and vivid branch, which is usually represented as a continuation of it, runs down from Gamma Cygni through Beta Cygni or Albireo, almost to the equinoctial, where it seems to lose itself in a region only sparsely supplied with stars.

In what is considered its widest part, namely the region between Orion and the Lesser Dog, it is about forty-five degrees in breadth, while in some of its narrowest portions, found between Cassiopeia and Perseus, and at a point in the Southern Cross, it is not more than three or four degrees in width. It is both broad and brilliant in the region between Cyngus, where it is of marvellous richness, and the southern horizon, but its most brilliant part lies south of the equator. In Sagittarius may be seen spots which, to the naked eye, appear as luminous knots, while close to Deneb in Cygnus is a typical instance of a star-stream, easily visible with a prism binocular.

Down in the southern Milky Way is a typical chasm,

known as the great austral "Coal-sack." It is the most famous dark gap or hole in the Milky Way, and is situated between the Southern Cross and Alpha and Beta Centauri, in a part of the sky, otherwise so bright that it is the more noticeable. This great gap is a dark, oval or pear-shaped spot, about eight degrees long, and five degrees wide, with a single, faint, naked-eye star in the centre, and a few scattered, telescopic stars. In this remarkable region, somewhat below the Coal-sack, is the place of nearest approach of the great galactic belt to the South Pole, which is situated near the sixth-magnitude star Sigma, in the constellation Octans, the antarctic equivalent of Ursa Minor.

There are a number of remarkable dark gaps or Coal-sacks, in Sagittarius, two of which, in the region near 8 M, are shown in Plate IX. Then, too, there is, in the northern hemisphere, a hole or dark gap in the Milky Way, similar to, though perhaps less perfect than, the great southern one, near the top of the cross-shaped figure in Cygnus, called the "northern Coal-sack in Cygnus." Many of the gaps or spots are true apertures, due possibly to the peculiar tendency of stars to accumulate in certain places, thus leaving others vacant, while some may be due to the presence of "dark nebulæ." A most interesting peculiarity, well seen during autumn and early winter, is the "great bifurcation"—that great rift dividing the Milky Way, from Cygnus in the northern hemisphere, all the way to Centaurus in the southern.

The mythology of the Milky Way is especially interesting. According to almost universal fable, it has been regarded as the bright highway—the "Broadway of the Heavens"—along which the Gods repaired to High Olympus, or it was the road traversed by

the souls of the departed on "the way," as Milton has it,

> To God's eternal home.

To the Algonquin Indians, not only was it the path of departed souls, but the brighter stars along its borders were the camp-fires that marked the halting places of the spirits on their weary march to the happy hunting-grounds. Longfellow alludes to this in *Hiawatha*, Chapter XV., in describing the journey of the gentle Chibiabos, the sweetest of musicians, to the land of the hereafter:

> Telling him a fire to kindle
> For all those that died thereafter,
> Camp-fires for their night encampments
> On their solitary journey
> To the kingdom of Ponemah,
> To the land of the hereafter.

And again, in narrating how the "wrinkled, old Nokomis nursed the little Hiawatha," he thus refers to the Milky Way:

> Many things Nokomis taught him,
> Showed the broad, white road to heaven.
> Pathway of the ghosts, the shadows,
> Running straight across the heavens.

By the ancient Mexicans the Milky Way was aptly termed the "Sister of the Rainbow." In Japan and China it was the "Celestial River." To the Norsemen and Scandinavians it was the path to Valhalla, up which went the souls of their warriors who fell in battle. To the Pawnee Indians, it was a cloud of dust kicked up by a buffalo and a horse racing across the sky. In

France it was known as "Le Chemin de Saint Jacques." It is "Die Jakobstrasse" (Jacob's Road) of the Germans, the mystic ladder, which the patriarch saw in his dream at Bethel, and beheld the "angels of God ascending and descending on it" (Genesis xxviii., 12). By the old English people it was sometimes called "Watling Street," "Asgard's Bridge," and the "Fairies' Path." By Bacon the Galaxy, the "Silver River of Heaven," is compared to fortune thus:

> The way of fortune is like the Milky Way in the sky, which is a meeting or knot of a number of small stars, not seen asunder, but giving light together. So are there a number of little and scarce discerned virtues, or rather faculties and customs, that make men fortunate.

The Magellanic Clouds

Situated in the southern hemisphere are the Magellanic Clouds, two remarkable objects, first named Cape Clouds, and otherwise known as the Nubecula Major and the Nubecula Minor. They were described, in 1516, by Corsali, and were named after the great Portuguese circumnavigator, Magellan. In appearance they resemble detached portions of the Milky Way. They are roughly of a circular form, and are situated in a locality singularly vacant of bright stars. They are nearer the South Pole than is the Galaxy, the Greater Cloud being in the constellation Dorado (the Swordfish) and the Lesser Cloud in Hydrus (the Little Water-serpent). The greater cloud covers a space in the sky of forty-two square degrees, and the lesser a space of about ten. While the lesser cloud almost entirely disappears in full moonlight, and the greater one loses a considerable

portion of its brightness, both are distinctly visible, in the southern hemisphere, on a clear, moonless night, and present a promiscuous intermingling of star-clouds, star-clusters, and gaseous nebulæ. No parallax has yet been found for them.

The Zodiacal Light

The Zodiacal Light, quaintly referred to by Elgie, in his *Night-Skies of a Year*, as that "elusive dream of quiet beauty, studied for centuries but mysterious still," may be defined as a faint, cone-shaped, pearly radiance seen in the west after evening twilight in the spring, and in the east before morning twilight in the autumn. It lies along the ecliptic, and, in a clear and moon-free sky, may be traced almost to the meridian south of the zenith, slanting up from the sunset glow in a line, which, in the northern hemisphere, leans towards the south. Its figure, which resembles a lens edgeways, is broadest close to the horizon, where it may be twenty-five or thirty degrees wide, and is brightest along its central line.

In northern and middle latitudes, this mystic light is visible in the evening about an hour and a half after sunset, from the middle of February to the middle of April, extending upward toward the Pleiades, and in the morning during September and October extending towards the south. It is usually much fainter than the Milky Way, though it has at times been seen brighter, and is sometimes taken for the twilight or dawn, but its nature may be readily recognised from its form, though it is somewhat difficult to determine exactly where its borders are.

In tropical regions, where it appears as a band of

light, rather than as a cone, it is visible the year round, about an hour or less after sunset, and is reported to be easily seen in full moonlight. It was known to the Arabs as the "False Dawn," and was called the "Zodiacal Light," because it lies within the circle of the zodiac. Attention was first directed to it in 1663 by a clergyman named Childrey, but the first particular description of it was by the elder Cassini (Giovanni Domenico) in 1683.

The exact nature of the light remains more or less a mystery, and all that can, with certainty, be said of it is that it exists. The polariscope and the spectroscope show it to be merely reflected sunlight. One theory regards it as the reflection of light from diffused dust, probably meteoric matter, revolving round the sun nearly in the plane of the ecliptic, while another supposes it to be a very faint extension of the sun's corona.

Occasionally a very interesting phenomenon, known as the *Green Flash*, is seen, in some latitudes, just as the sun is disappearing over the western horizon. It is characterised by the shooting up of a little green flame, and the turning green of the tiny tip that is left of the sun, just before it finally disappears.

The *Gegenschein*, the weird, "Counter-glow" to the sun, which travels through that part of the night sky immediately opposite the sun, is a faintly marked patch of light, somewhat oval in shape, from five to ten degrees in breadth, and ten to twenty degrees in length. It falls in the Milky Way in June and December and is then invisible. At other times it may be looked for on a perfectly clear and moonless night, when the sun is considerably below the horizon. The best time for observing it is in the autumn months, September and

15

October. It is, as Serviss says, "an extremely elusive phenomenon," seen only under the most favourable atmospheric conditions, and is generally considered as being of similar origin to the zodiacal light.

It was not discovered until 1854, and is looked upon by some astronomers as a sort of tail to the earth, seen sidewise, made up of hydrogen and helium, driven off from it, in a direction contrary to the sun. Professor Barnard, it may be observed, has devoted much attention to both it and the zodiacal light, in the endeavour to solve the mystery of these two strange appearances in the night-skies.

The Aurora Borealis

One of the most wonderful sights in the night-skies is the Aurora Borealis, a luminous, awe-inspiring phenomenon, manifesting itself by beams and streamers of light shooting up from the northern horizon toward the zenith, or appearing as an arch of light across the heavens from east to west. The streamers, which are generally rather brighter toward the west, often ascend in a fan shape, from a dusky line or segment a few degrees above the horizon. When the light extends southward beyond the zenith, it forms what is known as the corona.

The Aurora Borealis is popularly called the "Northern Lights," the "Northern Dawn," or the "Merry Dancers," and though sometimes seen in temperate latitudes, is viewed to best advantage in the Arctic regions, and is remarkable for the brilliant display of colours with which it is often accompanied. The prevailing colour in the higher latitudes is, it is said, usually white. When the colours brighten, they take

on a golden yellow tinge, the edges of the rays being marked by bands of red and green. Not infrequently, the display has the appearance of arches of fiery mist in the sky toward the north. The height of the Aurora above the surface of the ground, varies usually from about twenty-two to forty-four miles, though often it is as high as six hundred miles.

Observations show that auroral displays are more frequent before than after midnight, and that they are intimately associated with an outbreak of sun-spots and with terrestrial magnetic disturbances, the focus of the displays being in the north magnetic pole. In any locality the displays are more numerous in March and September, and are fewer in December, and again still fewer in June.

The Aurora is supposed, as suggested by Dudley, to be due to the presence in the atmosphere of a very rare, inert, gaseous element called *neon*, discovered by Ramsay in 1898, which has the property of becoming luminous when acted upon by magnetic discharges, whether of the earth currents or of streams of electric atoms called ions, sent forth by disturbances on the sun's surface. The displays, it is held, result from the neon gas, which becomes condensed by the cold near the poles, catching and holding the magnetic streams. A phenomenon in the southern hemisphere, of corresponding nature to the Aurora Borealis, and having its centre at the south magnetic pole, is called the Aurora Australis.

The beautiful primrose-coloured *Sun-glow*, that often lights up the northern sky during clear summer nights, is a sort of reflection thrown up by the sun, which at this season, in northern latitudes, does not sink very far below the northern horizon.

Nebulæ

Those strange, weird-looking, cloud-like celestial objects—worlds it may be in the making—which recent advances in celestial photography have shown to exist in different parts of the sky, are known as nebulæ (*clouds*) or "fire-mists." They are generally divided into two distinct classes, the *green* nebulæ, and the *white* nebulæ. Their chemical composition is thought to be very simple, and their extent is known to be colossal. So vast are they that many of them cover billions of times the space occupied by the solar system. Furthermore they are so extremely tenuous that they appear merely as faint spots of haze against the background of the sky.

Nebulæ of a greenish tint are found to be entirely in a gaseous condition, being composed of an unknown element named "nebulium," with which hydrogen and helium are associated. They were discovered as such by Sir William Huggins in 1864, and give a spectrum, a *discontinuous* one, consisting only of a few bright lines, chiefly green and blue, characteristic of the lighter gases. The wonderful and conspicuous Orion nebula is a striking representative of this class. Only a small minority of nebulæ, however, are green or gaseous nebulæ—bright-line nebulæ—and these tend to congregate in and near the Milky Way, most conveniently considered as the equator of the skies.

White nebulæ, such as the well-known spiral in the girdle of Andromeda, give a faint, so-called *continuous* spectrum, without dark lines, which denotes that they are composed either of gas under heavy pressure or great heat, or of something in a solid or liquid state. The great majority of nebulæ belong to this class, and

while distributed on either side of the Milky Way, they are rather remote from certain stretches of it, and crowd toward the northern galactic pole. In some regions of the sky nebulæ are more plentiful than stars, while in others they seem to be entirely absent. Many thousands of them exist, and about ten thousand have been catalogued.

Serving somewhat as a connecting link between nebulæ and the finished product are the so-called *nebulous stars*—stars buried in the depths of a faint nebulous haze. Their spectra show broader hydrogen and helium lines than the gaseous nebulæ, indicating that the gases are hotter and more condensed. Such nebulous stars are to be found in the Pleiades group, and in those connected with the Great Nebula in Orion.

> Far beyond Orion bright
> Cloud on cloud the star-haze lies;
> Million years bear down the light
> Earthward from those ghost-like eyes.
>
> FRANCIS T. PALGRAVE

Nebulæ are of various shapes, and, in certain cases, seem to be involved in a vast whirlpool motion. Some two or three of them are bright enough to be visible to the naked eye, while a few are within the range of small instruments. The majority, however, are so far off, that only an inadequate view can be had of them, even with the highest optical aid. Some nebulæ, the so-called planetary nebulæ, are small roundish or slightly oval objects, looking like ill-defined planets, and are of about uniform brightness throughout. The largest and finest representative of this class is known as the Owl Nebula in Ursa Major (Plate IV.), a few degrees from Merak. Others, like the Andromeda

Nebula (Plate XV.), are elliptical, while a few, like the so-called Ring Nebula in Lyra (Plate VII.), are annular, with a central condensation somewhat resembling a faint star. There are also nebulæ of irregular form, the most notable being the Great Nebula in Orion (Plate XVIII.), the Trifid Nebula in Sagittarius, and the Dumb-bell Nebula in Vulpecula (Plate VIII.), a small and inconspicuous asterism north of the Dolphin. Nebulæ which more or less resemble in appearance the telescopic comets have been termed cometary nebulæ. There are, in addition, a number of double nebulæ, and a few that are variable in brightness, the Trifid Nebula, above mentioned, being a notable variable.

The great majority of nebulæ, it is believed, have a *spiral* form, the one best showing its spiral nature being the famous Whirlpool Nebula of Lord Rosse, in Canes Venatici, the Hunting Dogs. Spectroscopical investigations have shown that *spiral nebulæ* generally exhibit the spectra of the white class, and yet bright lines due to glowing gases are sometimes seen. Almost invariably, they consist of a bright, rapidly rotating, disk-shaped, central portion, from which radiate two great spiral, flaming arms on opposite sides, like the streamers from a spinning pin-wheel, extending outwards to the limits of the spiral. They are much denser toward the centre, and along and in the arms of the spiral are bright knots, that look as if the nebulous matter were there condensing into stars, as clouds condense into drops, though no telescope has ever resolved these nebular knots or points of condensation into true stars. Professor Perrine of the Lick Observatory considered that with the Crossley reflector upwards of half a million spirals were visible.

The first successful photograph of a nebula—the

nebula in Orion—was made in 1880 by Dr. Henry Draper at Hastings-on-Hudson, N. Y. *En passant*, it may be noted that, up to the present, the finest nebular photographs have been made with reflecting telescopes.

Double and Multiple Stars

While to the naked eye most stars appear single, many are found by telescopic or spectroscopic aid to be double, triple, quadruple, or multiple stars. It has been estimated that one out of every six stars is a double or multiple star, though, according to Campbell of the Lick Observatory, a much larger percentage of stars will be found thus split up. In some cases stars appear double, seeming in fact to almost touch each other, because they happen to lie, like the street lamps in nearly the same line of vision, and yet one of the two components may be a vast distance beyond the other. Stars which thus appear double by the accident of perspective, and are not actually associated, are called *optical doubles*. Only a small portion of the stars, however, have proved to be really optical doubles. Certain stars, such as Mizar, Alpha Capricorni, Zeta Ceti, and Epsilon Lyræ, appear to be double, even when viewed with the unaided eye, and are loosely called double stars. Then, too, some true doubles are sufficiently "wide" to be easily divided by a prism binocular. Astronomers, however, do not consider a star double unless a telescope is required to separate its components. Generally, it may be said, a star whose components are less than three minutes apart cannot be divided without optical aid.

Those stars which stand close together, and form an actual physical system, (like, for instance, the moon and

the earth), and can be separated with the telescope, are *physical doubles*, and are called *visual* or *telescopic binaries*. They revolve round their common centre of gravity in elliptical orbits, at distances which, though limited, cover many hundred million miles. As far as at present known, their periods range from about five years to nearly sixteen hundred years or more. They have been plentifully found in every part of the sky. Moreover, many of the brightest stars in the heavens are binary stars. Among the most celebrated are Alpha Centauri, Gamma Virginis, and Sirius. About thirteen thousand are recorded in Burnham's great catalogue of double stars, and the number is fast increasing. Such dual systems as started as companions, not by direct collision but by tidal division, are looked upon as *twin suns*. In a large proportion of cases the two components are nearly equal in light-giving power, the companion stars being frequently blue and green. Not infrequently, however, the components are very unequal, a mighty star, it may be, being coupled up with a comparatively small one, in which case they often exhibit most beautifully contrasting colours. Among them may be found pairs of cherry-red and green, of orange and sapphire blue, of yellow and rose-red, of orange and purple, of orange and lilac, of yellow and white, of white and purple, of white and blue, of pale green and blue, and so on. Perhaps the most beautiful examples of the diversity of colours are Gamma in Andromeda, Beta in Cygnus, Epsilon in Boötes, Eta in Cassiopeia, and Iota in Cancer.

The shortest period for a visual or telescopic binary is that of the fourth-magnitude star, Delta Equulei, which has a fifth-magnitude companion, the swiftly circling pair completing their revolution in 5.7 years.

The well-known double star Castor has a period of 347 years and Zeta Aquarii one of about 750 years. Then, too, there are many binaries which probably take thousands of years to complete a revolution. The first star ever discovered to be double was Mizar, the star in the bend of the handle of The Dipper, and really a compound star, in 1650; and the first to be discovered telescopically as consisting of two stars close together was Gamma Arietis, in 1664; while the first binary to have its orbit satisfactorily computed was Xi Ursæ Majoris, its period of revolution being about sixty years.

Again, there are some stars which comprise so many constituents that they can best be described as *multiples*, cases where the telescope splits up an apparently single star into three, four, or sometimes six or seven separate stars, some of which may be dark bodies, even larger than the lucent ones. One of the best known of these multiple stars is Theta Orionis, the star in the nebula in the sword of Orion, which splits up into six components. Moreover, Epsilon Lyræ, a faint star on the frame of the lyre, close to the brilliant Vega, divides into seven stars; while Sigma Orionis, a star immediately below the lowermost star of the giant's belt, splits up, in a three-inch telescope, into six tiny dots of light. A star with eight components has been discovered in Lepus, and Burnham mentions one with sixteen components—a veritable stellar family.

Furthermore, there exists a class of stars which always appear single, even in the largest telescopes, and whose duplicity can be detected only by means of the spectroscope. Such stars are called *spectroscopic binaries*. Over three hundred such binaries are now known, and new pairs are being rapidly revealed. The

orbits of more than seventy have been fairly well determined, showing periods of revolution ranging from less than five hours up to nearly two and a third years. The distances between the two components vary from fifty thousand to nearly one hundred and five million miles. Hence it is apparent that the spectroscopic binaries are the fastest revolving couples. The transition from multiple or compound stars to closely grouped masses of stars called *clusters* is both a gradual and a natural one. A few star-clusters are resolvable to the naked eye, but most of them require a telescope to show the separate stars, though the instrument need not, in all cases, be one of high power. Most of the telescopic clusters are family groups like the double, triple, and multiple stars. They ordinarily cover an area of sky rather less than the average apparent size of the moon. Three of the most beautiful clusters were noticed and recorded by the ancients; namely, the well-known naked-eye group of the Pleiades, the scattered group of the Hyades, and the very effective, but fainter group Præsepe, long called the *Beehive*. Another somewhat scattered group of very faint stars is the small cluster called Berenice's Hair. Perhaps the finest of all irregular star-clusters is that situated in the sword-hand of Perseus, and sometimes called "Chi Persei." And, again, there is reason to believe that even the sun itself is a member of a rather open cluster of perhaps one hundred stars.

Throughout the heavens there are many so-called globular clusters, the grandest being those in Hercules, Centaurus, and Toucan, in which thousands of minute stars are closely packed together. There are over one hundred star-clusters now known, the finest being in the southern hemisphere. A remarkable group in the

Southern Cross is composed of 110 stars, seven of which only exceed the tenth magnitude; among the principal ones of this number, two are red, two green, one greenish-blue, and three others are pale green. So beautiful were the colours of this cluster that the great astronomer, Sir John Herschel, named it the "Jewelled Cluster."

Variable Stars

A remarkable peculiarity of a large number of the stars is to alter their brightness, either periodically or irregularly. All that thus change their brightness more or less are called *Variable Stars*, or *Variables*. Until near the close of the nineteenth century but little attention was paid to them. Now, more than a thousand variables are known, and perhaps three thousand more are comprised within star-clusters, while new members are constantly being discovered. Among the clusters that abound in variables are the Omega cluster in Centaurus, the clusters 13 M in Hercules, 3 M in the Hunting Dogs, and 5 M in Libra. It is even thought by some that all the stars, including the sun, are more or less variable. Their study is of more than ordinary interest to the amateur observer, possessed of good eyesight and the average amount of perseverance. Many variables are easily observed at maximum, and some even at minimum, without optical aid of any kind. Some are visible in a good opera-glass or prism binocular, while others need a two-and-a-half or three-inch telescope. Fine and quite accurate results can be obtained by the amateur in this most fascinating line of work with a three-inch glass or larger. Here, as in other branches of astronomy, photography has been employed with marked success, not a few of the

variables (including a number of insignificant ones) discovered in recent years having been found by the study of photographic star-charts.

Following the Harvard method of observing variable stars the observer may select a sequence of *comparison stars* for each variable, entering their photometric magnitude to the nearest tenth on a chart arranged for the purpose. From the position of the variable, as noted on a star-atlas, the star can be soon located by the telescope. Once it is identified, the observation of the variable consists in estimating the magnitude by the so-called method of relative comparison—comparing it with a brighter and then with a fainter star.

The American Association of Variable Star Observers, recently formed, will tend to foster an earnest co-operation in this special line of observational work.

Regarding the behaviour of a variable, it has been observed that the longer its period, the less is it disposed to follow regular laws, and that the shorter its period, the more precisely does it repeat its remarkable light changes.

In one type of variables, known as long-period variables, it will be found that the periods of the stars are long and irregular, sometimes varying considerably. None of the periods exceed two years, the majority cover about one year, and none are less than two months. Moreover, the maxima and the minima are apt to be more or less irregular; and the time from minimum to maximum is usually shorter than from maximum to minimum. Then, too, long-period variables quite characteristically show a rather ruddy light, especially when fading. The longer their period, the more red is their light. A remarkable representative of this class is known as Omicron Ceti, or Mira, the won-

derful star of Cetus. It has been under observation for over three hundred years, having been first seen by Fabricius, a Dutch observer, in 1596. It is a most noted object, and is the first variable star ever recognised as such. Its average period is about 331⅓ days, in the course of which it increases from the ninth to about the third magnitude, and then declines again to invisibility. Its period, however, is subject to various irregularities. Furthermore, sometimes at its maximum it is much more brilliant than at other times, occasionally, as in December, 1906, exceeding the second magnitude in brightness. It is estimated that at a bright maximum it emits fifteen hundred times as much light as at a low minimum. Its variations, as also those of long-period variables generally, remain as yet without any completely satisfactory explanation. The general idea nowadays is that they lie in the star itself, and may be due to the instability of light, as a result of advancing age. The majority of variables belong to this—the Mira Ceti—class.

There is another type of variables—the Algol type—which, at regular intervals, exhibit a rapid diminution in their light. There are some eighty such "winking" stars now known, and their periods range from about ten hours to nearly five days. Their variability is believed to be caused by a relatively dark companion eclipsing the bright star as the two revolve, close together, around their common centre of gravity. The majority of the stars of this type are white in colour, and in most respects are analagous to the spectroscopic binaries.

The typical star is Beta Persei—known as Algol, "the Demon," from its "slowly-winking eye"—whose variations can be easily watched without optical aid.

The star Algol is the most notable variable in the heavens, and, unlike Mira Ceti, runs through its cycle of variations not in months but in days. Its period has been determined with great exactness, so that its minima of brightness admit of easy prediction. It changes from the second to the third magnitude and back again once in about every three days (2 days, 20 hours, 48 minutes, and 55 seconds), and at its period of lowest brilliancy loses about three-fourths of its light. Its variability is apparently due to a huge, relatively dark body, partially eclipsing its light (just as the sun's light is cut off by the moon), as the two revolve, at close quarters, around a common centre of gravity, or perhaps about another invisible body, in an orbit turned edgewise to the earth. The distance of the relatively dark star from Algol is estimated at about thirty-two hundred thousand miles.

In the stern of the ship Argo, in the southern hemisphere, there is an Algol variable, both components of which are bright, and are believed to be circling around each other in actual contact. The period of light variation is estimated at about one and a half days.

A most interesting short-period, naked-eye variable and an easy telescopic double is the star Delta in Cepheus. It is a typical example of the Cepheid variables, which, unlike the Algol variables, have no period when the brightness is constant—the light changes being continuous. It changes from about the third and a half to the fourth and a half magnitude, and back again, in rather more than five days (5 days, 8 hours, 47 minutes, and 39 seconds).

Another remarkable short-period variable is the third and a-half-magnitude star Eta Aquilæ, which loses

rather more than a degree of its brightness, and recovers it again, in a little over seven days (7 days, 4 hours, 14 minutes, and 4 seconds). It is believed to be a spectroscopic binary, the companion star being too close to be revealed by the telescope. Its variations are easily followed with the naked eye.

Not less interesting are those variable stars of short period, closely related to the Algol variables, of which Beta Lyræ is the best-known example. In this class two unequal, self-luminous stars appear to revolve around each other in a plane passing through the earth, each eclipsing the other in turn during their revolution. The periods of these stars range from thirty days down to a few hours. The type star, Beta Lyræ—a star of "reciprocal eclipse"—is a triple star in a three-inch instrument, and an easy *double* for a two-inch. It is ordinarily of the third magnitude, (3.4), from which it passes in a period of rather less than thirteen days (12 days, 21 hours, and 47 minutes), through two minima, only the alternates of which are equal. At one minimum it fades to magnitude 3.9 and at the other to 4.5. Its variations are readily recognisable to the unaided eye, by reason of its close proximity to so bright a *comparison star* as Gamma Lyræ.

Of the irregularly fluctuating variables, the star Eta in the keel of Argo is perhaps the most conspicuous. It is unquestionably the most erratic of all the promitent variable stars. In the seventeenth century it shone as a star of the fourth magnitude, and a century later as one of the second magnitude, while in 1837 it was equal to Alpha Centauri in brightness. It then began to fade, but in 1843 it again blazed up, and reached the zero magnitude, ranking next to Sirius. Since then it has steadily declined, being at present

of only the seventh magnitude, and hence invisible to the naked eye.

Temporary Stars

Besides the variable stars, there are the ***new*** or ***temporary*** stars that have received the name of *Novæ*—stars which occasionally blaze out suddenly, in regions of the sky where none had been visible before, and then more or less quickly fade away, "as if a beacon out in the stellar depths had suddenly been fired." Such stars are most apt to break out in the Milky Way, and are characterized by a sudden rise to a great maximum, which, notwithstanding later possible increases, is never again attained. The earliest of these rather rare and erratic phenomena appears to have been observed by the Greek astronomer Hipparchus in 134 B. C., and which led to the compilation of his celebrated catalogue of stars. Chinese annals give picturesque account of a radiant temporary star that appeared in A. D. 173 in Centaurus, and remained visible for eight months. It was reported to have sparkled in five colours, and to have resembled *a large bamboo mat.*

The most celebrated of temporary stars, and the first of which there is any scientific record, flashed out in Cassiopeia in 1572. It was detected on the evening of November 11, of that year, by Tycho Brahé, though really discovered three months earlier by Schuler at Wittenberg. It was known as "Tycho's Star," and was as bright as Venus at her best, being seen distinctly in the daytime. It gradually waned until the spring of 1574, when it disappeared from view and has never since been seen. It has been fancifully identified with the "Star of Bethlehem," an assumption, however,

without any scientific foundation. A similar star appeared in the right foot of Ophiuchus in the fall of 1604. It was discovered by John Brunowski, one of Kepler's pupils, and was known as Kepler's Star. It was a white star of the first magnitude, and shone brighter than Jupiter. Its radiance slowly waned, and vanished early in 1606.

On May 12, 1866, a new star, almost as bright as the "Pearl of the Crown" (Gemma) itself, suddenly appeared in Corona Borealis. It soon faded, however, to the ninth magnitude, but is still visible with telescopes. It was discovered by Birmingham, and is known as the "Blaze Star" of the "Northern Crown." It is notable as being the first temporary star to be studied by the spectroscope.

In August, 1885, a new star of the sixth magnitude flamed out in the centre of the Andromeda nebula. It remained visible with telescopes for a few months, and then faded from view. Another temporary star was discovered in January, 1892, in Auriga, by Dr. Anderson at Edinburgh. At its full brightness, which it attained only gradually, this somewhat historic Nova, was of about the fourth magnitude. In three months it had sunk to the twelfth, but brightened during August to the ninth magnitude, after which it slowly faded out into a planetary nebula, a destiny which seems to await on temporary stars.

Early in the morning of February 22, 1901, Dr. Anderson discovered a brilliant Nova not far from the celebrated variable star Algol, in Perseus. It was nearly as bright as Tycho's Star, and was the most brilliant new star to appear since Kepler's in 1604. At the time of its discovery it was of 2.7 magnitude, but within two days it was brighter than Capella. Soon,

however, its radiance began to wane, and before the middle of April it had sunk to the fifth magnitude. It flared up again to almost the third magnitude, after which it faded away, and became lost to sight by the end of the year. Photographs taken with the reflecting telescopes at Lick and Yerkes observatories, some six months after its discovery, showed an extensive nebulous spiral encircling the star. Later the nebulosity disappeared, and the phenomenon, as it now exists, consists of a tiny telescopic star of the twelfth magnitude. The Nova first shone with a bluish-white light, which later turned yellow, and finally, as its radiance decreased, became red. As the star, according to commonly accepted estimate, is approximately three hundred light years distant, the so-called collision which caused the flare-up in 1901 actually occurred about the year 1600. It may here be mentioned, however, that some investigations, notably those of Bergstrand and Very, differently place the star's distance at from about sixty-five to one hundred and thirty light years only.

In March, 1903, Turner at Oxford discovered a new star in the constellation Gemini. It was of a crimson colour, and faded out rapidly, showing the usual tendency towards development into a nebula. Its spectrum indicated the presence of hydrogen and helium. On March 12, 1912, a new star, called Enebo's Nova, blazed out in the same constellation, about two degrees south of Theta. It was of a creamy-white colour, and of about the fourth magnitude, and was easily visible to the naked eye. Its brightness fluctuated markedly, though on the whole it diminished rapidly, and its hue deepened accordingly. Dark lines of uranium and radium emanation were found in its spectrum. It was

early in June, 1918, that a new star, Nova Aquilæ, suddenly blazed forth in the Soaring Eagle.

It is generally thought nowadays that the outbursts of temporary stars are the result of some sort of collision, although, as suggested by Barnard, the flare-ups may be produced by some sudden change in the stars' physical condition by forces inherent in the stars themselves.

Expressed in a general form, the prevailing idea, which is a modification of Seeliger's hypothesis, is that these outbursts are due to obscure bodies, extinguished suns, so to speak, encountering a vast invisible nebula, or wide-spread meteoric swarm, as they hurtle at almost unthinkable speed through space. Colliding with such masses with tremendous force, their surfaces are suddenly raised to incandescence, through resultant friction, just as tiny shooting stars are ignited by dashing through the earth's atmosphere. Furthermore, the nebulous or meteoric matter, hitherto dark and invisible, being suddenly lighted up by the new blazing star, is for the time rendered more or less distinctly visible. As the stars pass out of the material with which they have collided, their brilliant light quickly fades, inasmuch as their surfaces only are heated by the collision. And again, the secondary flare-ups that are at times observed in temporary stars, are, it is believed, due to secondary collisions with invisible masses of nebulous or meteoric matter.

During the past twenty-five years about seventeen new stars have been seen, of which no less than fourteen have been found by the energetic force of Harvard College Observatory.

CHAPTER VIII

STELLAR DISTANCES

Behold the height of the stars, how high they are!
JOB xxii., 12.

IN measuring the distance of a celestial body, or, as astronomers say, determining its parallax, the calculation may be readily made by a method similar to that used by surveyors in the measurement of terrestrial distances. In general, parallax—from the Greek παραλλαξις a shift or alternation—may be defined as the apparent displacement of an object as a result of the change in position of the observer. By way of illustration, let the observer hold his finger or a pencil, a foot or more in front of him. Upon looking at it with first one eye and then the other, he will notice that it seems to change its position with reference to any object beyond it. Now this apparent change in position of an object to its background, when viewed alternately from two separate points, is technically termed a parallax.

In astronomy, different names have been applied to the parallax of a heavenly body, according to the different positions of the observer or observers and the body. The *geocentric* or *true* place of the moon, or any other celestial body, is that in which it would be seen by a hypothetical observer at the centre of the earth. The *apparent* or *observed* place is that in which it is

actually seen by a real observer on the surface of the earth. The *parallax* of a body, called also its *geocentric* or *horizontal parallax*, is the difference in direction between its true and apparent places. It is the angle subtended (measured) by the semi-diameter of the earth from any body of the solar system. The angle subtended by the earth's *equatorial* semi-diameter is termed the *equatorial horizontal parallax*. The *annual* or *heliocentric parallax* is the angle subtended (measured) by the semi-diameter of the earth's orbit, from the more distant fixed stars.

In the measurement of the distance of any inaccessible object, when the base-line, namely the distance between the points of observation, is known, and also the angles formed by the lines of direction at the opposite ends of the base line, it is easy to find by simple trigonometry the other parts of the triangle, and to calculate how far off the object is. Applying this principle to ascertain the distance of celestial bodies, the longest base-line that can be obtained on earth, is about eight thousand miles—the diameter of the earth. A longer line in space, is the entire diameter of the earth's orbit or about one hundred and eighty-six million miles. For convenience of calculation, astronomers employ the *radius*, or *semi-diameter*, in either case instead of the whole diameter for a base-line. The semi-diameter, or equatorial radius, of the earth is used as a base-line for measuring the distances of the moon and nearer planets, and the semi-diameter, or mean radius, of the terrestrial orbit, for measuring the distances of the stars.

A simple, though perhaps not the most accurate, method for ascertaining the distance of the moon, the nearest celestial body to the earth, consists in observing that satellite, from widely separated points on the earth,

but in very nearly the same longitude. Let observers at the two places determine at the same instant, with a meridian-circle or some equivalent instrument, the moon's zenith distance. From the directions of the moon thus ascertained, and the distance apart of the observers, which is known to start with, it is easy to find by a simple trigonometrical process the moon's distance.

Following roughly the methods of Young, Serviss, Poor and others, let M in Fig. 2 represent the moon, A

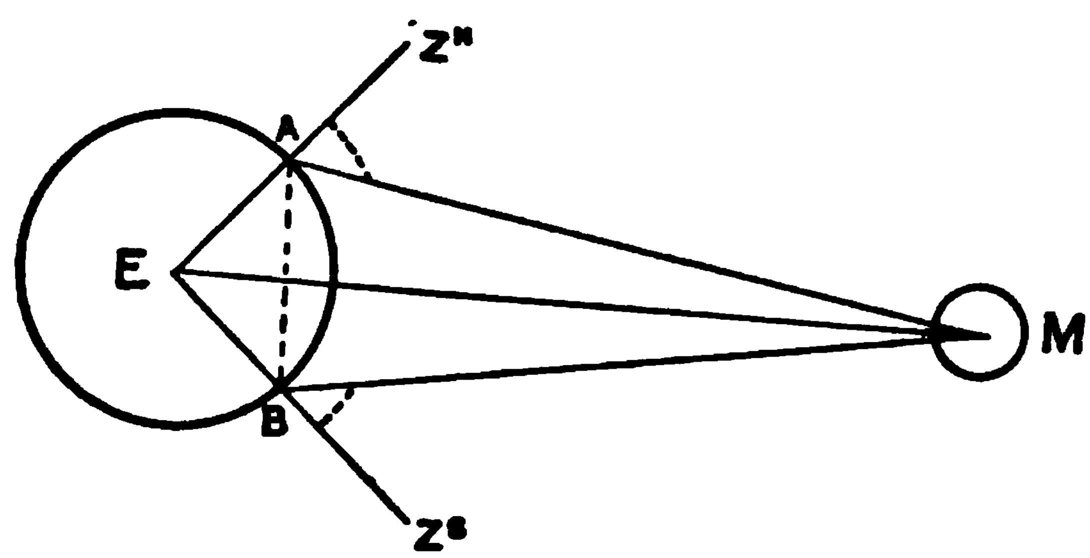

FIG. 2. The Measurement of the Moon's Distance.

the location of an observer in the northern hemisphere, B the location of another observer in the southern hemisphere, and E the centre of the earth. The zenith of the observer at A is in the direction E A Z^n, and that of the observer at B in the direction E B Z^s. The angle A E B at the centre of the earth is equal to the latitude difference of the observers at A and B. The sides A E and B E being radii of the earth, their length is known. Hence the angles E A B and E B A can be easily calculated. Subtracting these two angles respectively from E A M and E B M gives the interior angles M A B and M B A. And as the length of the side A B is already known, for it is the distance apart of the

two observers, the sides A M and B M can be readily found.

Now in the triangle E A M or E B M, as the two sides and the included angle are known, it is easy to find the other parts of the triangle, and to compute the distance from the centre of the earth to the moon, E M. The moon's mean parallax is found to be 57.2′ which corresponds to 60.3 times the earth's equatorial radius, or 238,840 miles.

The foregoing is the simple method, on the theory that the earth is a sphere of uniform density. But the earth is not a sphere, nor is it of uniform density. Therefore, in practice, allowances, which are small, are made for these conditions, and thus proper values of the radii and angles are obtained for use in the computations.

In estimating the distance of the sun, as its direct determination by the measurement of the solar parallax, after the manner of the lunar parallax, is practically impossible, other and indirect methods have been employed. Among these may be mentioned the parallaxes of Mars and of some of the planetoids (determined best by heliometer observations or from a series of photographs), the transits of Venus, the aberration of light (a phenomenon which is the result of the combined effects of the velocity of light and of the earth's orbital motion), and various irregularities in the motions of the moon, the inner planets, Venus and Mars, and the planetoid Eros.

A most simple method, easy to understand, is that known as Delisle's method (Fig. 3) which takes advantage of various observations of the transit of Venus across the sun's disk, a phenomenon that last took place on December 6, 1882, and will not occur again

until June 8, 2004. At the moment of transit, Venus is only some 26,000,000 miles from the earth, and its parallactic displacement is over two and a half times that of the sun.

Illustrating Delisle's method after the manner of Young, Serviss, and others, let E in Fig. 3 represent the earth, A and B the stations of two observers on opposite sides of the earth, on or near the equator, and on a line roughly parallel to the planet's motion, and S the sun. The observer at A notes the instant

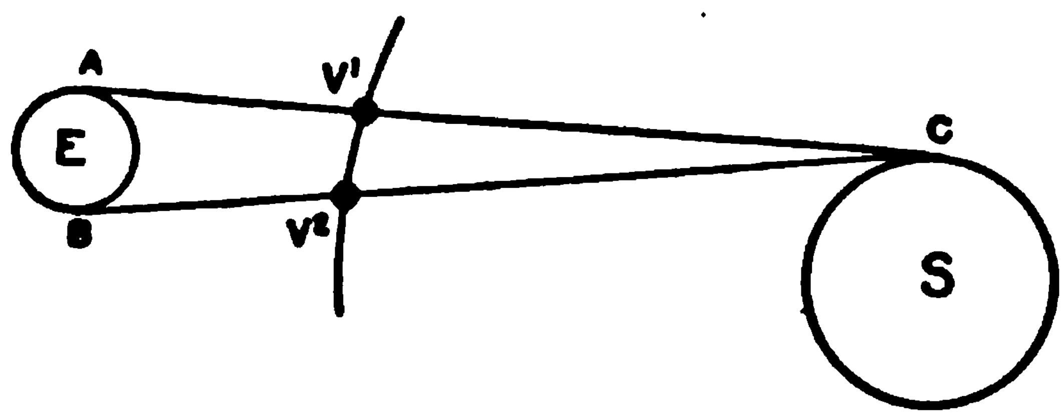

FIG. 3. The Measurement of the Sun's Distance. (Delisle's method.)

at which Venus (then at V^1) appears to touch the sun's edge, while the observer at B notes the instant when the planet is at V^2. From the time occupied in passing from V^1 to V^2, and the known synodic period of the planet (584 days), the size of the angle A C B may be calculated. And as the distance between A and B, the earth's diameter, is already known, it is easy to compute the length of other lines in the triangle, and hence the sun's distance from the earth. Up to within the last thirty years, most of the estimates for determining the sun's distance were based on transit of Venus observations. Now, however, since other and more accurate methods have come into use, the transit has lost much of its former importance.

The best of the geometrical methods for measuring the solar parallax is probably that used by Gill in his observations of Mars, on Ascension Island in 1877, in which all the observations are made from a single station, by a single observer, when the planet is near its rising and its setting points. From the distance that the observer has been carried by the rotation of the earth on its axis (which can be easily calculated from the time that has elapsed between the observations), and the measured shift of the planet among the stars, the whole parallax may be readily computed, and thence the distance of the planet.

Since the discovery of Eros by Witt of Berlin, in 1898, one of the most important methods for determining the sun's distance is based on observations of this tiny planetoid, which periodically approaches much nearer to the earth than any other body of the solar system, except the moon. In 1931, Eros will be most favourably situated for observation, as it will then approach to within some fifteen million miles of the earth, which is much nearer than Mars or Venus ever do. Knowing the distance of the planetoid, the distance of the sun can be readily calculated, for by Kepler's *third law* (page 270) the relative distances of the different planets from the sun are proportional to their periods of revolution about the sun. The latest determination based on observations of Eros, at its opposition in the autumn and winter of 1900–1901, places the solar parallax at the value 8″.807, which corresponds to a distance of about 92,820,000 miles.

And again, one of the most simple and striking of the several indirect methods makes use of the velocity of light, which has been determined with great precision by methods of measurement which will be found

explained in special treatises in physics. By observing the eclipses of Jupiter's satellites, it has been found that light takes about sixteen minutes, thirty-six seconds, to cross the terrestrial orbit, or eight minutes, eighteen seconds to reach the earth from the sun. Now, multiplying the known velocity of light—186,400 miles a second—by eight minutes, eighteen seconds, or 498 seconds, gives approximately the sun's distance.

In calculating the distance of a star, its direction in the sky at epochs six months apart should be accurately observed, the distance between the points of observation being the mean diameter of the earth's orbit. From the displacement measured at these intervals of time, which is *twice* the annual or heliocentric parallax, the star's distance may be computed. A paltry few out of the entire host of stars change their apparent positions when thus observed, but the changes are only slight, no star having been found that alters its position as much as one second. The great bulk of the stars are at such inconceivable distances that even the magnificent base-line of 186,000,000 miles proves insufficient, in most cases, to produce any perceptible change in their direction.

Within recent years the fashion has been to have the measurements for the determination of a star's distance made with the measuring machine, upon a photographic plate taken with a photographic telescope. When the distance can be gauged, the star should, if persistently watched, appear to oscillate in a yearly period, as the earth moves round the sun. On account of the immense distances of even the nearer stars, the oscillations are, however, almost immeasurably small. Knowing the range of the oscillation, the distance of the star is immediately deducible.

The first satisfactory measure of a star's parallax, namely that of 61 Cygni, was obtained by the Prussian astronomer Bessel, in 1838, by means of the Königsberg heliometer. Since then the *actual distances* of some seventy odd stars have been counted, although *approximately correct parallaxes* have been secured for many more. From photographs made at an interval of seven or eight years on the same plate, Kapteyn and Weersma have, it is said, deduced the parallaxes and proper motions of over three thousand stars. The parallax of the visual binary, Alpha Centauri, the nearest known star, which is but 0.75 seconds of arc, and corresponds in round numbers to a distance of about twenty-six million million miles, is the largest yet ascertained, and was announced by Thomas Henderson, the great Scottish astronomer, while employed as the Astronomer Royal at the Cape of Good Hope, in 1839.

Spectrum Analysis and Celestial Photography

When a narrow ray of sunlight passes through a triangular prism of glass or of any other transparent substance, it is not only refracted, that is, bent from its original course, but is also spread out lengthwise into a fan-shaped band of rainbow colours. Collected on a screen these primary or prismatic colours, seven in number, pass imperceptibly from violet, which is refracted the most, at the one extremity, through indigo, blue, green, yellow, and orange to red, which is refracted the least, at the other end (Fig. 4). Beyond the violet rays, which have the shortest wave-length, are a series of shorter waves called the ultra-violet (invisible), actinic, or *chemical rays*, and beyond the red rays, which

have the longest wave-length, are a series of longer waves, called the infra-red (invisible), or dark ***heat rays***. This separation of white light into its various components is called ***dispersion***, and the ribbon-like rainbow-tinted band called a ***spectrum*** is, when produced by sunlight, known as the ***solar spectrum***.

Light from a candle flame, a star, a nebula, or other

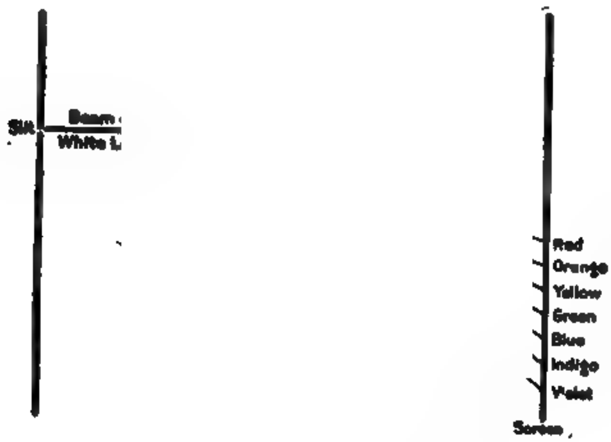

FIG. 4. The Dispersion of Light by the Prism.

luminous object, will produce a similar band or spectrum, but the appearance of the band, with regard to the preponderance of different colours, will depend upon the source and character of the light. By receiving the spectrum on a concave mirror, or by passing it through a convex lens, or through a second prism reversed, all the spectrum colours may be recombined, so as to form a single beam or band of white light. When a body absorbs all the colours of the spectrum except one, but reflects that colour to the eye, the body is said to be of that colour, be it blue, green, or other colour; if it re-

flects or gives back *all* the colours to the eye, it then appears white.

As early as 1802, the celebrated English chemist and physicist, Wollaston, noticed that the solar spectrum is crossed by numerous *dark* lines, like narrow gaps, of various thicknesses, and at irregular distances from each other. Later in 1814, these lines were carefully studied and mapped by Josef von Fraunhofer, an eminent optician of Munich, and are therefore called *Fraunhofer's lines*. On a tombstone, erected to the memory of the scientist in a Munich graveyard, is this epitaph: "He brought the stars nearer to us."

The real meaning of Fraunhofer's lines remained a mystery, until 1859, when a German physicist, Kirchhoff, discovered the secret (namely, that these dark lines indicate the presence of certain substances in the sun), and opened up a new and exact method of investigation, since known as *Spectrum Analysis*—recently voted the sixth wonder of the modern world.

Three principles were announced by Kirchhoff as underlying the theory of spectrum analysis: The first principle or law is, that a solid or a liquid body, or a gas under high pressure, gives, when incandescent, a plain or *continuous spectrum*—a coloured band of light devoid of lines.

The second principle or law is, that incandescent gas under low pressure gives a *discontinuous spectrum*—a spectrum made up of bright-coloured lines on a dark background, the colour, position, and number of the lines being dependent on the nature and constituents of the gas.

The third principle or law is, that if the light from a body giving a discontinuous spectrum has to pass through a layer of gas having a lower temperature, the

gas will absorb rays of identical colour or wave-length with those composing its own bright-line spectrum, dark lines, or gaps—the Fraunhofer lines—replacing the characteristic bright lines in the spectrum of the gas itself. Spectra of this kind are styled *absorption* or *dark-line spectra.*

The spectroscope, an instrument devised for the production and study of spectra, and which was first applied to astronomical observation about 1864, consists, as usually constructed, of three parts—a collimator, a dispersion piece (either prism or grating), and a view-telescope. The collimator or small telescope has a narrow adjustable slit, through which the ray of light enters, at one end, and a double convex lens so placed at the other end that the light will pass from the collimator in parallel lines. The prism, or diffraction grating, effects the dispersion necessary to produce a spectrum, and the small view-telescope is of use in examining the different regions of the spectrum. To the amateur a pocket spectroscope, such as Browning's, is highly useful.

The power of the spectroscope may be increased by adding to the number of the prisms, or in other words using a train of prisms. Not infrequently the prisms are replaced by ruled gratings, the spectrum given by which is called the *normal spectrum,* because the amount of dispersion of the rays is proportional to their wave-lengths. The diffraction grating, invented by Rowland in 1883, consists of very fine parallel equidistant lines, from five thousand to twenty thousand to the inch, ruled on glass or on speculum metal. From such gratings spectra of wide dispersion are obtainable.

For the study of that class of spectroscopic binaries, to which Mizar, the larger component of the well-

known double star in the tail of the Greater Bear, belongs, in which the lines of the spectrum periodically double and undouble themselves, the slitless or objective-prism spectroscope has been found particularly effective. The spectroheliograph, a still further development of the spectroscope, devised by Hale in 1892 for the purpose of photographing the solar prominences, permits of photographs being taken of the sun with the light of one element at a time, and by its means a composite photograph of the entire solar surface can be built up.

By means of the spectroscope the astronomer is enabled to determine, from certain shifting of the lines in the spectrum, the direction and rate of a star's radial motion, that is, its motion in the line of sight. If the lines are displaced toward the violet end of the spectrum, the star is approaching, and if toward the red end, it is receding, the rate of speed, which is proportional to the amount of displacement, being readily calculated by laws of optics. Then, too, the spectroscope has given the means of studying many interesting features on the sun, and has shown, from their characteristic spectral lines, that forty or more of the elements known on earth are present in a gaseous or vaporous state in the sun.

In addition, it has revealed that many of the terrestrial elements are present as glowing vapours in the gaseous envelopes of the distant stars, that the greenish, bright-line nebulæ are masses of incandescent gases, and that throughout space, matter is essentially the same. With its help it has been possible to estimate the age of a star, to tell if it was young, or at full radiance, or past its prime, or perchance on its way to extinction. It has revealed that the inner parts of Saturn's rings

rotate faster than the outer ones. Then, too, it has rendered it possible to recognise as double, certain stars —spectroscopic binaries—which even the most powerful telescopes have failed to separate.

Within recent years the studies of the spectra of stars, nebulæ, and other celestial objects have been made almost wholly by photography, the camera being adjusted to the telescope, and the object photographed being examined and measured in detail at leisure. The photographic plate has rendered it possible to portray star-clouds and extensive nebulæ, and to determine the positions of stars with an accuracy that would be otherwise unattainable. It has recorded the existence of numerous faint and far-off stars, which have never been seen by simple visual observations with even the largest telescopes. It has assisted in picking out the tiny planetoids, and in the discovery of the minute moons in the vicinity of Jupiter and Saturn. Then, too, on the photographic plate the whole moon has been pictured with an accuracy far beyond anything possible by manual drawing.

The first photograph, or rather daguerreotype, of a celestial object was one of the moon, secured by Dr. J. W. Draper of New York in 1840, while the first photograph of a star was that of Vega, taken at Harvard College Observatory in 1850 under the direction of the elder Bond (William Cranch). The first photograph, or rather daguerreotype, of a solar eclipse was made in 1851 by Dr. Busch at Kônigsberg, and the first photograph of a solar prominence was obtained by Young with the old wet-plate process, in 1870. In 1872, Dr. Henry Draper, the son of Dr. J. W. Draper, secured the first photograph of the spectrum of a star, and in 1880, the first successful photograph of a nebula.

Part II

The Sun and the Planets

CHAPTER I

THE PLANETESIMAL HYPOTHESIS, AND OTHERS

That very law which moulds a tear
And bids it trickle from its source,—
That law preserves the earth a sphere,
And guides the planets in their course.

SAMUEL ROGERS.

To the unassisted eye the most beautiful and interesting objects in all the heavens are found among the radiant wandering bodies called planets (from the Greek word πλανήτης the *wanderer*), which have a proper motion of their own among the stars. Held by gravitational influence from travelling away into space, these bodies revolve substantially in one plane, at varying distances, and at varying rates, from west to east, in orbits of various degrees of eccentricity, around a great central globular mass, the Sun, the nearest of the stars. That limited portion of the universe, a little under fifty-six hundred million miles across, occupied by the Sun and its eight large planets with their twenty-six satellites, together with about eight hundred tiny planets, called planetoids or asteroids, and a whole number of cometary and meteoric bodies, so largely isolated from all the other systems of the universe, is known as the "local" *Solar System.*

It is now thought probable that before there were any planets at all or any sun, there existed a comparatively

small, flat, rapidly rotating spiral nebula, out of which in the lapse of indefinite ages the solar system was evolved. According to the Chamberlin-Moulton theory, put forth in 1905—the most satisfactory theory yet advanced in regard to the origin and development of the solar system, and known as the Planetesimal or Accretionary Hypothesis—the primal spiral nebula was formed, millions of years ago, by the grazing[1] collision or the near approach (within Roche's limit of about 2½ diameters) of a great, dark, solid body, an extinguished sun, with another body as it hurtled incognito through the icy regions of space. In the spinning nebulous mass formed as a result of the cataclysmic shattering of the bodies, brought about by their terrific impact, or through their disruptive tidal influence on each other, the matter, it is held, was very diffuse at the outer edge of the irregular spiral, and densest in the centre, while scattered here and there along and in the two fiery, coiled arms, projecting from diametrically opposite sides of the whirling figure, so noticeable in almost all spiral nebulæ, knots or spots of condensation appeared.

In the process of evolution, the denser globular centre became the controlling sun, the mighty ruler of the system, and the nebular knots or local condensations on the arms of the spiral separated from the parent mass as the nuclei of the individual planets that were to be. These planet nuclei continued to revolve about the original centre, and in proportion to their mass gathered in by gravitative attraction more or less of the scattered material—wandering

[1] It is held by Bickerton and others that the collision could not be other than a *grazing* collision, as, under the laws of attraction, such bodies can never meet centre to centre.

planetesimals or fragments—that chanced to pass near their orbits. Such condensations of matter on the arms of the spiral as happened to be of good size at the time of separation from the parent mass, gathered up large quantities of the small and slow-moving particles of ejected matter which the region afforded, and thus developed by aggregation into large planets. Nuclei located near the outer edge of the spiral, and which formed the outer or the major planets, were composed of the lighter material of the nebula, while such as were nearer the centre, and formed the inner or the terrestrial planets, were composed of the denser material.

In some instances, the planet nuclei at the time of separation from the parent body picked up and carried away with them, to become their satellites, such of the smaller condensations of the widely distributed matter —secondary nuclei—as were swift of motion and were far enough away from the original centre to remain under their gravitational control. And again, shapeless fragments of matter destined to form tiny worlds, called planetoids or asteroids, whirled in irregular orbits, in the vast space between the two widely different groups of planets—the inner and the outer—where, by gravitative influence of one of the larger planets (Jupiter), condensation was disturbed, and no large body was allowed to form. Whilst left-over bits of matter—the "last ungathered remains" of the primal nebula—perchance, formed those small celestial objects called comets and shooting stars, which journey in orbits of every degree of eccentricity, and are part and parcel of the solar system.

In a recent book on *The Evolution of Worlds*, by Percival Lowell, it is suggested that,

What brought about the beginning of the system may also [in default of other causes] compass its end. If one random encounter took place in the past, a second is as likely to occur in the future. Another celestial body may any day run into the Sun, and it is to a dark body that one must look for such destruction, because they are so much more numerous in space. That any of the lucent stars could collide with the Sun is demonstrably impossible for æons of years. But this is far from the case with a dark star.

Judged [however] by any scale of time we know the chance of such catastrophe is immeasurably remote. Not only may each one rest content in the thought that he will die from causes of his own choosing or neglect, but the Earth itself will cease to be a possible abode of life, and even the Sun will have become cold and dark and dead so long before that day arrives that when the final shock shall come, it will be quite ready [for another awakening into activity].

The hypothesis of ring formation, put forward by Pierre Simon, Marquis de Laplace, the eminent French astronomer, in his famous *Exposition du Système du Monde*, in 1796, to account for the birth of the solar system, plausible as it appears, and which was formerly accepted in its entirety, is found not to account for many present-day details of the system. This now celebrated Laplacian hypothesis began by assuming a rotating, lens-shaped, intensely heated nebulous mass, that slowly contracted as its heat radiated into space, and threw off rings of fiery vapour which broke up and condensed into separate globular masses, destined to form the planets. These planet balls revolved around the central condensation, which was ultimately to form the Sun, in the same general direction as the ring had revolved, and in turn con-

tracted, some throwing off rings of matter which later, it was thought, broke up and condensed to form attendant satellites.

Tennyson, in *The Princess*, Part Second, thus alludes to this beautifully simple, but somewhat discredited theory of the order and way in which the solar system developed into its present complex state:

> This world was once a fluid haze of light,
> Till toward the centre set the starry tides,
> And eddied into suns, that wheeling cast
> The planets.

In this connection it may be noticed that an interesting theory of cosmical evolution has recently (1909) been advanced by T. J. J. See and others, termed the Capture Theory, between which and the accretion theories of Chamberlin and Moulton there seems to be much in common. In a general way it assumes that the order of the universe is the incessant expulsion of tiny particles of dust from the stars by radiant energy, into space, there to collect into cosmical clouds or nebulæ, with the drifting together and condensation of nebulæ into stars and stellar systems, as gravitation reasserts its force—the world-process being, as one of its advocates has said, "an eternal cycle of centralisation and dispersion."

According to this theory the spiral nebulæ out of which stars and systems are evolving are formed by the close approach of two nebulous streams, and their curling together in the exercise of mutual gravitation, or by the curling up of a single nebulous stream by reason of its own gravitation. By concentration of the knots or condensations of nebulous material within the spirals thus formed, sun-centres are supposed to be

produced. It is also supposed that these suns by their capture of neighbouring knots or condensations develop systems of planets, while the planets in turn capture systems of satellites. Or again, the suns may draw together into binaries, triple or quadruple star-systems, or into magnificent star-clusters.

Such are the hypotheses in regard to the origin and development of the solar system, and they remain hypotheses which are by no means eternal.

CHAPTER II

THE LOCAL SOLAR SYSTEM (*A Synopsis*)

And God said, Let there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons and for days and years.

GENESIS i.,–14.

THE most important of all the celestial bodies, so far as the inhabitants of the earth are concerned, is the Sun (Plate XX.), the giver of light and heat and energy, and to whose beneficent rays highly organised life here owes its existence and its perpetual propagation. This mighty orb, which is roughly estimated as over seven hundred times larger than all the planets and satellites of the system put together, and was called by the late Schiaparelli the "most magnificent work of the Almighty," is about 864,750 miles in diameter, and some 92,820,000 miles distant from the Earth.

It is so large that were it hollowed out like an immense rubber ball, and the Earth placed at its centre, the Moon could revolve at its present average distance of about 239,000 miles, and there would still be room for another satellite to circle in an orbit over 190,000 miles exterior to the Moon's orbit. And again, so far off is it, that a railway train, which, travelling night and day at the uniform rate of sixty miles an hour, could

make a circuit of the Earth in seventeen days, and a journey to the Moon in 5½ months, would take 176 years to reach the Sun, and about 5¼ years to travel round it. Then, too, this same train, travelling at its sixty-miles-an-hour rate, would take over 5300 years to

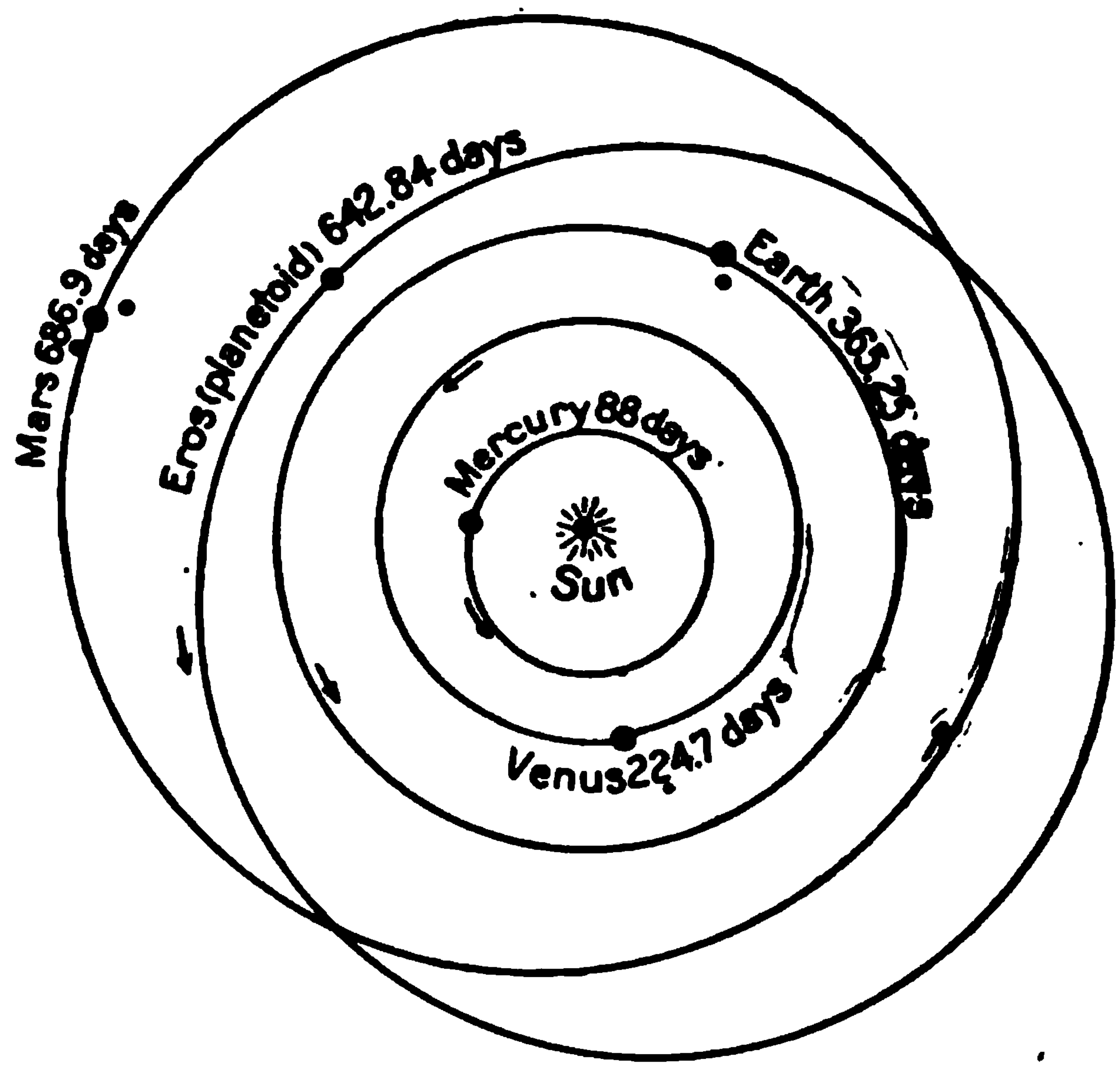

FIG. 5. The Orbits of the Terrestrial Planets.

make the trip to the orbit of Neptune, the present known boundary of the local solar system.

The planets, which may be divided into two principal classes—the inner or terrestrial, and the outer or major—are dark opaque bodies that are illuminated by the Sun as they circle round it, their relative distances from which have generally a rough kind of order that follows what is known as *Bode's Law.* They are believed to have been evolved, as mentioned in the previous chapter, from various nuclei which existed in the

original spiral, and are all of the same age. The inner or terrestrial planets (Fig. 5) were evolved from small nuclei, and are all of them relatively small in size, and rather dense in structure. They are also comparatively near together, travel at higher speed, and have few or

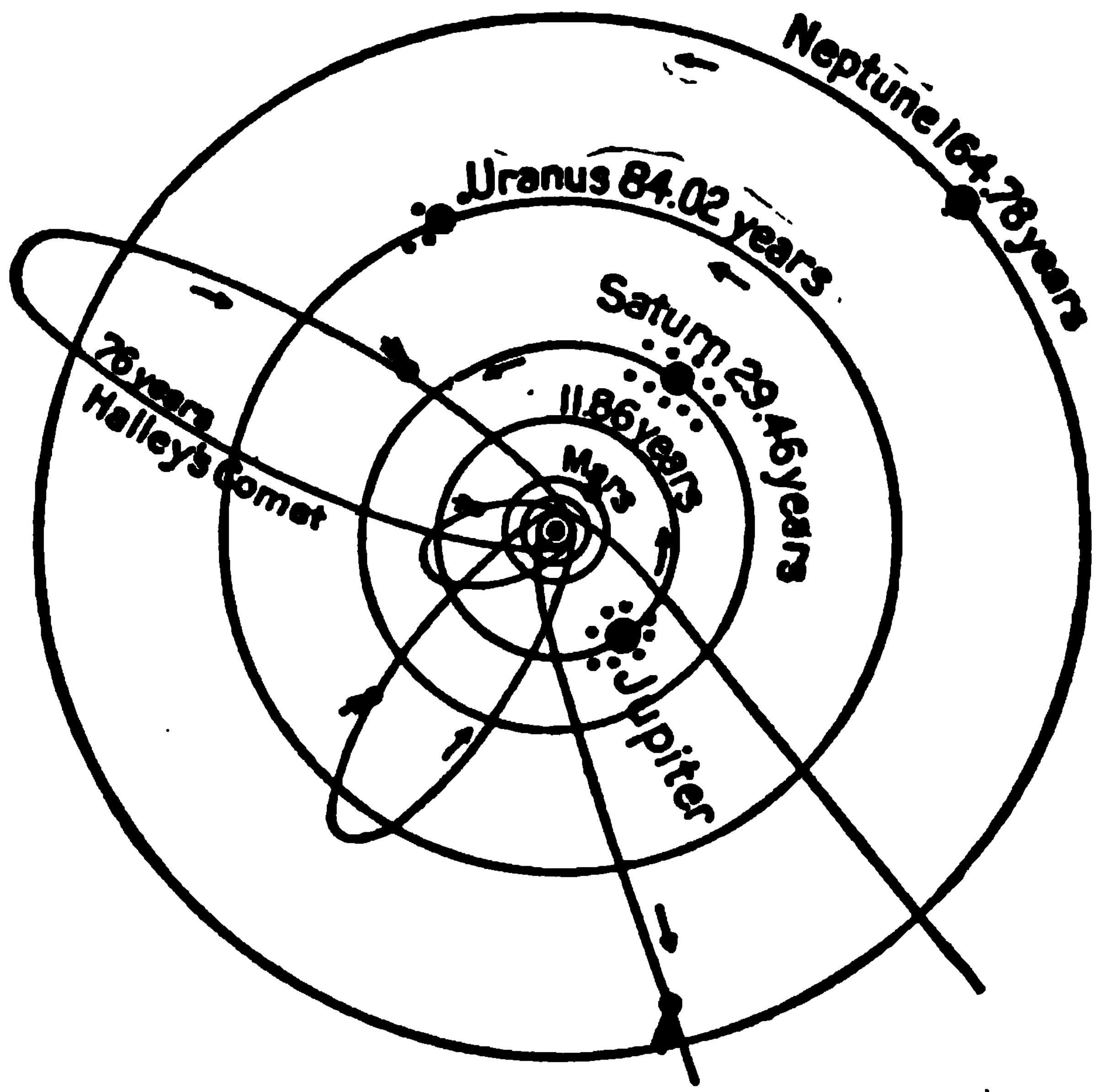

FIG. 6. The Orbits of the Major Planets.

no satellites. The outer or major planets (Fig. 6), on the other hand, were evolved from great nuclei and are huge, rather vapoury bodies, not quite so advanced in their planetary history. They are enormously distant from one another, travel more leisurely, and have, as a rule, imposing retinues of attendants.

The planets that are nearer the Sun than the Earth is are sometimes called inferior planets, and those which are farther from the Sun, superior planets. Planets

whose orbits lie between the Earth and the Sun have very different phases and apparent motions from those whose orbits lie beyond the Earth from the Sun. When an inferior planet lies between the Sun and the Earth, and nearly in line with them, it is in inferior conjunction, and when on the far side of the Sun, it is in superior conjunction. It is at greatest eastern elongation when at its greatest apparent distance east of the Sun, and at greatest western elongation when at its greatest apparent distance west of it. When it is west of the Sun, it rises earlier than the Sun, and is a morning star, and when east of the Sun, it sets later than the Sun, and is an evening star.

A superior planet is in conjunction when on the far side of the Sun, and is then at its greatest distance from the Earth. It is in opposition when it is nearest, that is, when it is behind the Earth and in line with it and the Sun. All the planets, when nearest the Earth, appear for a relatively brief time to move slowly backward. Then, too, a planet usually describes more or less of a loop or flourish, as it thus seems to pass back and forth among the stars. This apparent retrograde motion, in a superior planet, occurs when the Earth is overtaking and passing it, and in an inferior planet, when it is overtaking and passing the Earth.

When viewed through the telescope, planets appear as round globes, like little worlds in fact, differing in this respect from stars, which seem to be only points of light. They have no light of their own, as the stars have, but their measurable disks reflect the sunlight, and their light is far steadier than that of the stars. They follow a general track or path called the zodiac, so that each planet is always somewhere in the zodiac, and is said to be *in* the constellation that forms its

apparent background. Such as can be seen with the naked eye are most of the time much brighter than any first-magnitude star. Occasionally Uranus can be seen with the naked eye, as a star of the sixth magnitude, while Neptune, which is about as bright as an eighth-magnitude star, can be seen only with the aid of a good field-glass, or a telescope. It will be found that by looking up their positions with the aid of the *American Ephemeris and Nautical Almanac*, published annually by the United States Government, they may be the more readily recognised.

All the planets, and all the satellites that belong to them, revolve in their orbits round the Sun, in the opposite direction to the hands of a clock, and they all —except Uranus and Neptune and their satellites, and the eighth and ninth satellites of Jupiter and the ninth of Saturn, which rotate in a "retrograde" or backward direction—rotate on their axes in the same "counter-clockwise" way. And further, all the satellites of the planets, so far as is definitely known, turn the same face always to their primary, just as the Moon does to the Earth. Then, too, a time will come, though far remote, when, like Mercury and Venus, each of the six remaining planets will turn an unchanging face to the Sun, the father of them all.

The motions of the planets in their orbits take place in accordance with three very important laws, discovered by the famous German astronomer, Johann Kepler, and therefore called *Kepler's Laws*.

The first law (announced in 1609) is, that the orbits of the planets are ellipses, having the Sun in one of the foci.

The second law is, that the radius vector of a planet —that is, an imaginary line joining the planet to the Sun

—passes over equal areas of space in equal periods of time.

The third law (published in 1619) is, that the squares of the periods or times of revolution of the different planets about the Sun are proportional to the cubes of their mean distances from the Sun. By way of illustration, suppose the period or time of revolution of one planet is eight times as long as that of another planet, then by Kepler's law the mean distance of the first planet from the Sun will be four times that of the second planet. This number is reached by taking the square of eight and then extracting the cube root, which is four. Knowing, therefore, the distance of the first planet, that of the second planet may be readily found, by simply dividing the distance of the first planet by four. This third law is known as Kepler's "harmonic law."

Newton interpreted these laws of planetary motion and showed with certain limitations, that they are the direct consequences of one fundamental law of nature, the Law of Universal Gravitation. This empirical law (announced in 1687) is, that all bodies in space attract one another with a force directly proportional to the product of their masses, and inversely proportional to the square of their distances apart.

The *inner* or *terrestrial* planets consist of four worlds, namely, Mercury, Venus, the Earth, and Mars. As far as is known, Mercury, the "Sparkling One," is the nearest to the Sun of all the planets. Its period of rotation and of revolution are the same, so that it always keeps the same side toward the Sun, and has no alternation of day and night. The eccentricity of its orbit is greater than that of any of the principal planets, so that at times it is half as far off again from the Sun as at others. As

its orbit is inside that of the Earth, Mercury is visible only either in the evening or in the morning sky. It is never seen very far above the horizon, and owing to its proximity to the Sun—being never more than about 28° from it—is difficult to observe with the naked eye. Nevertheless, if the observer knows where to look, it is easy to pick up the elusive little planet, before it sinks below the horizon, especially with the aid of an opera-glass. It is said that the celebrated astronomer Copernicus lamented in his last moments (May, 1543) that he had never been able to see it. Gassendi attributes the failure to the mist and vapour so very prevalent along the banks of the Vistula, where Copernicus lived.

The next planet in order outward from the Sun is Venus, the "Beautiful," the most radiant of all the planets, outshining heaven's host. It is remarkably like the Earth in size, so much so as to be called its "twin-sister," and is in about the same stage of planetary life. Like little Mercury, it turns on its axis in the same time that it revolves round the sun, and in consequence it turns always the same face to him, and has no alternation of day and night. Its orbit, in contrast with that of Mercury, is remarkable for the smallness of its eccentricity. Being nearer than the Earth to the Sun, Venus, like Mercury is visible only either in the evening or in the morning sky, and is never much more than 45° from the sun. Then, too, like Mercury, it exhibits *phases* (Fig. 7), invisible to the naked eye, which recall those of the Moon. Its light is of a dazzling whiteness, while that of Mercury is slightly reddish.

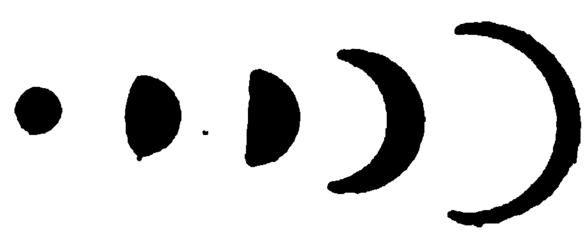

FIG. 7. The Different Phases of Venus.

So intense is its brilliancy at the time of its greatest brightness (Plate XXVIII.), that its light often casts a shadow, and, not infrequently, it may be seen with the naked eye in broad daylight. In *The Telescope*, The Honorable Mrs. Ward writes:

Late in the evening of January 24, 1854, when both the sun and moon were sufficiently out of the way, the planet Venus being in its position of greatest brilliancy shone with a remarkable lustre. We observed it in a room with a single window, every sash of which was imaged on the ground, as it would have been in moonlight, and even the slight waves and concentric lines on the panes could be clearly traced.

The next planet outward is the Earth, which shines by reflecting the light received from the Sun, as all its planetary neighbours do, and which from the nearer planets must appear as a brilliant star, as it revolves in its slightly elliptical orbit. It occupies a most unique position in the universe, for not only is it the abode of man, but it is the only world of which human beings have any direct knowledge. It is a remarkably smooth globe, and departs but slightly from the spherical form, being flattened at the poles only about *twenty-seven* miles. This flattening, however, as Bayne says in his *Pith of Astronomy*, "leads to the truthful but paradoxical statement, that the Mississippi River runs up hill, as its mouth is three miles farther from the centre of the earth than is its source." It is attended by one faithful satellite, the "moon divine" of Southey.

Passing outwards, the next planet is Mars, the "Red Planet" (Plate XXXIV.), one of the most interesting objects in the heavens, which in its days and seasons closely resembles the Earth. From its many points of resemblance to the latter planet, some astronomers are

inclined to believe that Mars may be a habitable world. Being only a little over half as large as the Earth, it has run more swiftly through the stages of its evolution, so that planetary old age has already set in. Its average temperature is commonly believed to be much lower than that of the earth, and probably below the freezing-point of water. Its orbit is more eccentric than that of any other of the principal planets except Mercury, and it marks the limit of the inner or the terrestrial group of planets. Seen with the naked eye, as a bright red star shining with a steady light, it expands under telescopic power into a broad disk of a fiery orange colour, with spots and markings upon it of a dark greenish-grey or bluish-grey tone, and an all-embracing network of ill-defined blue-green streaks termed "canali" or channels (Plate XXXV.). At the poles it is capped with bright white rounded spots, supposed to be snow, the so-called "polar caps." Oliver Wendell Holmes thus poetically writes:

> The snows that glittered on the disk of Mars
> Have melted, but the planet's fiery orb
> Rolls in the crimson summer of its year.

Mars is never very brilliant except when it is in opposition—that is, when it is on the same side of the Sun as is the Earth, and nearly in line with them—which happens once in about seven hundred and eighty days. Its next opposition will occur in January, 1914, from which time it will be visible in the evening, until the following autumn. It has two small satellites, named Deimos and Phobos, which are remarkable for the extraordinary rapidity of their motions. In his satire, *Gulliver's Travels*, published in 1726, Dean

Jonathan Swift makes his hero tell about the astronomers on the Flying Island of Laputa being so very clever that they had discovered two moons circling round Mars, one of which went round the ruddy planet in ten hours. This was considered a most wild fancy, as no moon known then, revolved round its primary in a shorter time than the latter took to turn on its axis. But in 1877, a century and a half later, Asaph Hall at the Naval Observatory, Washington, found that Mars had two moons, and that one of them (Phobos), a rather gay little satellite, revolves even faster than Mr. Lemuel Gulliver of Wapping said, taking only seven hours and thirty-nine minutes to complete its orbit.

Beyond the orbit of Mars stretches a vast space, in which circulate an all but innumerable host of very tiny worlds called planetoids or asteroids. Their orbits are more eccentric than those of any of the principal planets, and the periods of revolution vary from about two to twelve years. Up to the present time about eight hundred of them have been listed, and new ones are being found every year, principally by means of the photographic plate. The biggest of them, Ceres, is less than five hundred miles in diameter, and many of them are not more than ten or twenty miles. All of them are invisible to the naked eye, with the exception of Vesta, which though not much more than two hundred miles in diameter, happens to be the brightest, and under favourable conditions can sometimes be seen without optical aid. One of the most erratic of these tiny bodies, named Eros, has a large portion of its orbit within that of Mars, and comes at times nearer the Earth than any other celestial body except the Moon or an occasional comet. It has been estimated that the total mass of

the whole planetoid group is less than one-quarter that of the Earth.

Outside the zone of the planetoids, which forms the dividing-line between the inner and outer quartette of planets, rolls the mammoth planet Jupiter (Plate XXXVI.), the greatest and most magnificent member of the Sun's family of worlds. It is over thirteen hundred times as big as the Earth, and is larger than all the other planets put together. So big is it that even in a small telescope it looks as large as the full moon looks to the unaided eye. Its great size having tended to keep it young, it is probably still a semi-sun, though not so much of a one as to shine by its own light. And yet there are reasons for believing that its surface is not altogether dark, and that it may, at least, have a dull-red glow. That it shines by reflected sunlight is evidenced, however, by the fact that its own moons receive no perceptible light from it.

Its light has a yellowish-white tint, and is remarkably steady. Near the time of opposition, which occurs at intervals of three hundred and ninety-nine days, it may be easily recognised in the evening sky, when it is, next to Venus, the brightest star-like object in the heavens. It will be in opposition early in August, 1914, in Capricornus, and will be a brilliant and commanding object in the summer sky.

No planet, it is said, presents such a fine opportunity for colour-study as does Jupiter. When viewed with a good telescope, its broad bright disk appears covered with belts and spots of various colours and varying shapes. On each side of the equator are two very distinct, cherry-red belts, called the tropical belts. Then too, traversing all of the bright belts, wisps or lacings may be detected, and just below the southern tropical

belt is the celebrated Great Red Spot, which has been more or less visible since the summer of 1878. So far as is known, Jupiter is attended by nine satellites, four large and five small, the four larger ones being among the easiest objects for a small telescope. Its fifth, a very small satellite, is notable as moving faster than any other satellite in the solar system. In addition, Jupiter has an adopted "Comet family" of some thirty-two comets, made prisoners to the Sun, by its disturbing influence. Its period of rotation is shorter than that of any other planetary body, being on the average about nine hours and fifty-five minutes.

The sixth of the planets in the order of distance from the Sun is Saturn (Plate XXXVII.), the show member of the Sun's planet family. It is the second largest planet in the solar system, its diameter, roughly speaking, being about one-fifth less than that of the planet Jupiter. It is a spheroidal globe and is more flattened out at the poles and bulged out at the equator than any other planet. In proportion to its size, it is the lightest of any of the planets, its density being so small that it is actually lighter than water. It is almost twice as far from the sun as is Jupiter, and is, in all probability, at an earlier stage of evolution. To the unaided eye it appears as a dull, red-yellow star of about the first magnitude. When seen through a good telescope it is, perhaps, the most wonderful and beautiful object in all the sky. It has been beautifully alluded to as the *Te Deum* of the heavens—an oratorio of the night—and yet with all its grandeur it is a far less noble creation of God than is a human soul. It is surrounded by cloud-belts, similar to those which encircle its giant neighbour, but its colouring is not nearly so bright or so varied.

Saturn's most unique feature is its magnificent sys-

tem of rings, surrounding it above the equator. The entire diameter of the ring formation is rather more than 172,000 miles, the breadth about 38,000 miles, and the thickness about eighty miles. The rings are supposed to consist of innumerable meteoric particles, each circling in its own individual orbit, but all keeping so close together that they appear like three solid concentric rings, whirling continually around the planet. They are so thin, that this page is probably thicker compared to its breadth, than they are compared to theirs. They are wholly unlike anything to be seen elsewhere in the heavens, and are known respectively as Ring A, the outermost one; Ring B, the middle one; and Ring C, the crêpe or gauze ring, nearest to the body of the planet. They are brightest and most open when the planet is *in* either the constellation Scorpio or the constellation Taurus. Saturn is now (January, 1914) in opposition in the easterly part of Taurus. It will be at its brightest about the third week in December, 1914, when in opposition near the border line between Taurus and Gemini, at which time the southern side of the wide-open rings may be seen.

Outside the rings, Saturn has no fewer than ten moons circling round it in ceaseless revolution. One of them, called Titan, is a bright and big moon about the size of the planet Mercury, and is quite a little world in itself. The vastness of Saturn's realm will be at once apparent when it is known that the distance from the planet to its outermost moon is nearly eight million miles. A prism binocular field-glass will disclose the rings, but the belts and moons require a more powerful instrument, while some of the latter are almost at the limit of visibility.

Beyond beautiful Saturn is Uranus, the seventh planet from the Sun, and fourth in order of size. It is

considered to be the smallest of the major planets, its diameter being calculated as but little more than four times that of the Earth, although some measurements, including that by Barnard, place it above Neptune in point of size. It is a largely vaporous and much expanded body, and has a density only one-fifth greater than that of water. On account of its distance from the Sun, which is about twice that of Saturn, and nineteen times that of the Earth, it receives but little solar heat and light. When near opposition it may be seen with the naked eye as a star of about the sixth magnitude, and yet few observers can see it without optical aid.

In a good telescope it appears as a very beautiful, pale, greenish-blue planet, and under favourable conditions faint markings may be seen traversing its neat round disk. A remarkable thing about Uranus is that it is enveloped in a dense atmosphere of enormous extent. It rotates in a "retrograde" or backward direction, but it revolves in the direction pursued by all the other planets—that is, "counter-clockwise." It rotates like a top rolling on its side, and in that position revolves round its orbit on its great annual journey of about eighty-four terrestrial years. It is attended by four faint satellites, which revolve around it at about its equator, in a retrograde or backward direction, in orbits nearly perpendicular to its own orbit. It was named after the god whom the Greeks believed to be the father of Saturn.

Uranus remains *in* each constellation somewhere near seven years, travelling a little more than four degrees a year. It is now (January, 1914) in Capricornus, about twenty-four degrees east of the Milk Dipper in Sagittarius. It was in opposition in 1913 on July 29th, and will be in opposition in 1914 on August 4th.

Farther afield, on the frontier of the solar system, some twenty-seven hundred million miles away,[1] is lonely Neptune, draggling along its nearly circular orbit at the comparatively leisurely pace of three and two-fifths miles a second. It is the eighth and, so far as is known, the most distant member of the Sun's family of worlds. It is commonly ranked the third largest of all the planets, although some measurements make Uranus the larger of the two. Like Uranus, it is enveloped in a large and dense atmosphere, and it is celebrated for having been discovered by means of computations based on its disturbing attraction on that planet. It was located in Aquarius by a young astronomer, John C. Adams, of England, and a young mathematician, Urbain LeVerrier, of France, and at the latter's request Galle, at the Berlin Observatory, searched for and found it less than one degree from the spot indicated, on September 23, 1846. At first it was called LeVerrier but was later, at the suggestion of LeVerrier, more fittingly named after Neptune.

It shines as brightly as an eighth-magnitude star, and, though invisible to the naked eye, can be seen with a good prism binocular field-glass. In a large instrument it exhibits a small, weakly-illuminated, bluish or leaden-tinted disk, on which no definite markings have as yet been seen. Its axis is even more tilted over than that of Uranus, and it rotates in this extraordinary position in a "retrograde" manner, but performs its orbital revolution "direct," as all the other planets do. As far as is known, only one single, nameless, satellite (Plate XL.) adorns the skies of Neptune. Like Rudyard Kipling's cat, it "walks by itself." It is about

[1] Vast as this distance may seem, the very nearest of the stars proper —Alpha Centauri—is over nine thousand times more distant.

as bright as a fourteenth-magnitude star, and has, like the Uranian moons, a "retrograde" motion. It was discovered by Lassell on October 10, 1846. Neptune is now (1914) in the constellation Gemini, south of and not far from Castor and Pollux. It remains on an average about thirteen years in each constellation.

For some time the existence of an extra-Neptunian planet has been strongly suspected, from indications of its influence on the motions of certain comets, as also on the movements of Neptune. But the numerous photographic as well as telescopic searches hitherto made for it, have been without success. Quite recently, however, the orbit of a remote hypothetical planet has been again calculated, and its position announced as certain. Possibly it may later be detected, if such a planet exists, as seems most likely. Its calculated distance from the Sun is rather more than nine thousand million miles, or over three times Neptune's distance.

Besides the planets and their moons, but totally unlike them, are those most interesting celestial objects called comets and meteors—the most erratic members of the solar family circle. Scattered, as they are, in unknown millions, throughout the system, these strange and mysterious, yet harmless, things are, as they speed across the sky, only visible for the brief period they are in the vicinity of the Sun and the Earth.

No more unique and apt illustration of the relative sizes, distances, and motions, in the local solar system has been devised than that suggested long ago by Sir John Herschel, in his *Outlines of Astronomy:* On a wide level field or common, place an ordinary library globe, two feet in diameter, to represent the Sun. At a distance of 82 feet from it put a mustard seed, to represent Mercury; a pea at a distance of 142 feet, for Venus;

another pea at a distance of 215 feet, for the Earth; and a rather large pin's head at a distance of 327 feet, for Mars; and minute grains of sand at distances varying from 500 to 600 feet, to represent most of the planetoids. Place a fair-sized orange at a distance of nearly a quarter of a mile to represent Jupiter; a small orange at a distance of two-fifths of a mile for Saturn; a large cherry at a distance of three-fourths of a mile for Uranus; and lastly a fair-sized plum at a distance of a mile and a quarter to represent Neptune.

According to this scale the daily motion of Mercury in its orbit would be thirty-six inches; that of Venus, twenty-four inches; that of the Earth, twenty-two inches; that of Mars, eighteen inches; that of Jupiter, ten and a half inches; that of Saturn, seven and a half inches; that of Uranus, five inches; and that of Neptune, four inches. On the same scale the Moon would be represented by a smaller seed than Mercury, moving in a circle at a distance of six and two-thirds inches from the pea which represents the Earth, with a daily motion of about two-thirds of an inch, and the nearest star would be located on the opposite side of the earth, several thousand miles away.

In the Academy of Sciences, Lincoln Park, Chicago, is a rotating Celestial Sphere, fifteen feet in diameter, in which are represented the brighter stars of the different constellations that are visible from the latitude of Chicago. In addition to the stars, the Sun and Moon are represented, as also are the planets Venus, Mars, Jupiter, and Saturn. The sphere is constructed of light galvanised sheet-iron, and is provided with an observer's stationary platform, and a circular horizon table. It was invented by Wallace W. Atwood, and was presented to the Academy by La Verne W. Noyes.

TABLE OF SOLAR AND PLANETARY STATISTICS

Names	Sun	Mercury	Venus	Earth	Mars
Average distance from the Sun, in millions of miles		36	67.2	92.8	141.5
Period of revolution round the Sun		87.97 days	224.7 days	365.25 days	1 year and 321.65 days
Mean diameter in miles	864,750	3400	7630	7918	4230
Mean speed of revolution per second		29 miles	21 miles	18 miles	15 miles
Average period of rotation	25 days 7 hrs. 48 min.	Equals time of revolution	Equals time of revolution	23 hrs. 56 min. 4 sec.	24 hrs. 37 min. 22.65 sec.
Mean density in proportion to the Earth	0.25	0.85	0.89	1.00 (5.5 compared with that of water)	0.71
Surface gravity. Fall in feet per second	442.4	6.9	13.7	16.1	6.1
Number of satellites		0	0	1	2

TABLE OF PLANETARY STATISTICS (*Continued*)

Names	Planetoids	Jupiter	Saturn	Uranus	Neptune
Average distance from the Sun in millions of miles	135.5 to 488	483	886	1782	2791.5
Period of revolution round the Sun	1.76 to 12.1 years	11.86 years	29.46 years	84.02 years	164.78 years
Mean diameter in miles	10 to 477	87,380	73,120	31,900	34,800
Mean speed of revolution per second	8 to 15.5 miles	8.1 miles	6 miles	4.2 miles	3.4 miles
Average period of rotation		9 hrs. 55 min.	10 hrs. 14 min.	12 hrs.	?
Mean density in proportion to the Earth		0.24	0.13	0.22	0.20
Surface gravity. Fall in feet per second		42.6	18.9	14.4	14.3
Number of satellites		9	10	4	1

Mean distance of the Moon from the Earth	Period of revolution of the Moon round the Earth	Mean diameter of the Moon in miles	Period of rotation of the Moon	Mean density of the Moon in proportion to the Earth
238,840 miles	27 days, 7 hrs. 43 min. 11.15 sec.	2163	Equals time of revolution	0.61

CHAPTER III

THE SUN

> The disk of Phoebus, when he climbs on high,
> Appears at first but as a blood-shot eye,
> And when his chariot downwards driven to bed,
> His ball is with the same suffusion red;
> But mounted high on his meridian race,
> All bright he shines and with a better face.
>
> OVID (Dryden's tr.)

THE mighty orb of the Sun—the lantern of the world (*lucerna Mundi*), as Copernicus called it—is, as noted in a previous chapter, the centre around which the little family of worlds which constitute the local solar system travel. It is a hot, self-luminous, yellowish-white, whirling globe, composed of gases and metallic vapours, powerfully compressed by its strong self-gravity (Plate XX.). It appears to be rather more than half a degree in diameter, and seems a trifle larger (nearly two per cent.) in winter than in summer, the Earth then, being about $3\frac{1}{10}$ million miles nearer to it. It rotates on an axis inclined about $7\frac{1}{4}°$ from a perpendicular to the plane of the ecliptic, in the same direction as do the planets, making a rotation in about $25\frac{1}{4}$ days. Not being a solid body, the different parts of its surface rotate at different rates, the velocity being greater at the equator than toward the poles. Hence, while the period of rotation at the equator is about

Yerkes Observatory

PLATE XX. The Solar Disk
(Showing calcium flocculi)

twenty-five days, it is approximately twenty-seven days at midway between the equator and the poles. Besides, the sun has a motion in space, since, at a velocity of thirteen miles a second, it is carrying the whole solar system in the direction represented by the "apex of the Sun's way," a point in the sky fairly near the star Delta in Lyra. And again, the motion of the Earth around the Sun causes it apparently to move eastward among the stars 30° every month in the year.

The surface temperature of the Sun has been roughly estimated at about 15,000° Fahrenheit, which is several thousand degrees above that obtainable in the most powerful electric furnace, and its light, which reaches the earth in eight minutes, at about one hundred and forty-six times that of a calcium light, and three and two-fifths times that of the intensely brilliant "crater" of the electric arc. In addition, observations show that the radiant energy received from the Sun on every square yard exposed perpendicularly to its rays is equivalent to about three horse-power—a horse-power being the unit of work that will raise thirty-three thousand pounds one foot high in a minute.

What becomes of nearly all of the light and heat sent out by the Sun is not known, as, if it is radiated equally in all directions, the Earth intercepts only about the one twenty-two-hundred-millionth part of it, and all the planets together not more than one-hundred-millionth part. As compared with the Earth, the Sun has 332,000 times as much mass or quantity of matter, and exceeds it in bulk about 1,300,000 times.

At the Sun's surface, the force of gravity is rather more than twenty-seven times that at the surface of the Earth. Hence a man who on the Earth weighs 150 lbs. would, if transported to the Sun, weigh nearly

behind the eyepiece of the telescope, and let the image of the sun be projected upon the screen. Or again, the sensitised plate may be substituted for the screen and a photograph obtained, which can be examined at leisure.

To the amateur observer, the chief objects of interest on the bright solar disk are those relatively dark, irregular spots called "sun-spots" (Plate XXI.). They usually appear, not singly, but in groups, and generally follow certain definite zones, mostly lying between 10° and 35° north or south heliographic latitude. They are the most conspicuous markings ever observed on the Sun, and are regarded by many as emblems of advancing age. Their average lifetime is two or three months; sometimes, however, they disappear in a day, and again they have been known to last as long as eighteen months. They are, as demonstrated by Hale, in 1908, probably great electrical vortices or whirling storms, and are regarded as somewhat analogous to cyclones, tornadoes, or water-spouts on the earth. The vortex in the solar atmosphere has, it is believed, a spiral structure, and may be either right-handed or left-handed in its direction, while the effect of the vortical motion is to draw into the spot gases from the upper solar atmosphere, which are ejected from the spot at lower levels. The gases present in the nucleus of a sun-spot have a considerably lower temperature than on the surface of the Sun outside of the spot, owing, it is thought, to their cooling by expansion in the axis of the vortex.

In a typical spot, the dark central portion is called the umbra, and the lighter irregularly shaded grey portion around it the penumbra. The umbra of a spot is not really dark but only relatively so with

Yerkes Observatory

PLATE XXI. The Great Sun-Spot of July 17, 1905

respect to the brilliant envelope of the Sun—the photosphere—as it is actually more brilliant than the electric arc. Frequently a spot will be seen to be crossed by one or more brightly shining plume-like projections called "bridges" (Plate XXI.). Generally the surface in the neighbourhood of the sun-spots seems more or less raised, and the spots themselves are usually above the general surface of the photosphere. In size, sun-spots vary greatly, ranging from five hundred to fifty thousand miles in diameter, and sometimes a penumbra surrounding a group of spots will measure from one to two hundred thousand miles across. The area of one spot photographed at Greenwich in March, 1905, was nearly forty times that of the entire surface of the earth. Not infrequently sun-spots are large enough to be seen with the naked eye, either when the sun is low on the horizon, or during the day, through a piece of smoked or coloured glass. Such spots as can be seen with the unaided eye, it may be noted, are at least four times the size of the Earth. About thirteen and a half days (13 days, 14.5 hours) are required for a spot to travel across the solar disk from its eastern edge, or limb, to the western, and a similar period of time to reappear at the eastern edge.

A rather remarkable fact regarding sun-spots is that they are more numerous at some seasons than at others, and that they increase and decrease at stated periods. According to the latest researches, the average length of the sun-spot cycle, as this increase and decrease is called, is 11.1 years. Usually the spot-maximum follows the preceding spot-minimum, after about four and a half years, while the minimum happens about six and a half years later than the maximum. The period, however, is not one of absolute regularity,

a variation amounting to as much as two years being possible in either direction. There will be a sun-spot maximum in 1915. Generally the spots of a given period are first seen some 35° from the solar equator, and as the period progresses, they increase in size, reaching their greatest numbers when their latitude is about 20°. Then they begin to diminish both in number and size and die out as they draw toward the equator.

The sun-spots are found to be strong magnetic fields, and their periods appear to coincide closely with various magnetic and electric phenomena on the Earth. When spots are numerous on the Sun, violent magnetic storms and brilliant auroras are found to be numerous on the Earth. Furthermore, some writers say, there are reasons for believing that there may be some connection between the average temperature and rainfall and the relative frequency and size of sun-spots.

Besides the spots, and readily seen with a small instrument, are the "faculæ" or *little torches*—bright ridges or patches scattered irregularly over the solar surface. They are from one thousand to more than forty thousand miles in length, and from about one thousand to nearly four thousand miles in breadth. They appear to be elevated above the general level, and are best seen near the edge of the solar disk. The faculæ are the brightest parts of the Sun, and are especially abundant and active in the vicinity of sun-spots. Unlike the spots, however, they are found everywhere, except in polar latitudes. Moreover, a facula standing alone is generally looked upon as the precursor of a sun-spot forming at that site.

Closely connected with the faculæ are the red flames or "prominences" (Plate XXII.), which like the sun-

Plate XXII. A Large Solar Prominence (two views)
(October 10, 1910)

spots increase and decrease about every eleven years. They are projections from a layer of prominent gases —the chromosphere—surrounding the photosphere. They are of a brilliant red colour—due to glowing hydrogen—when viewed in profile, at the edge of the sun, but white when seen in projection against the intensely brilliant solar disk. Their average height is about fifty thousand miles. Occasionally, however, they attain an altitude of from one hundred and fifty thousand to over three hundred thousand miles. The velocity of their ascent varies from about three hundred to over five hundred miles a second. On October 7, 1880, Young measured a prominence and found it to extend three hundred and fifty thousand miles beyond the edge of the Sun, and Hale, on March 25, 1905, with his then newly invented spectroheliograph, photographed a prominence that increased from one hundred and thirty-five thousand to two hundred and eighty-one thousand miles, while Rambaut, at Oxford, noted on November 15, 1907, a prominence which rose to a height of nearly three hundred and twenty-five thousand miles. Formerly it was necessary to wait for a solar eclipse to see the prominences, but now they are observable at any time in broad daylight, with the aid of the spectroscope.

Solar prominences, or protuberances, as they are sometimes called, are broadly divided into two classes—the eruptive and the quiescent—which differ markedly both in size and character. The quiescent prominences are cloud-like forms composed mainly of hydrogen and helium and, though found over all parts of the Sun's surface, are most numerous in the neighbourhood of the poles. They assume all kinds of shapes, tend to spread horizontally, and are frequently of large

size. While, as a rule, they are never of great height, at times their elevation is from forty thousand to sixty thousand miles. They are not very brilliant, alter their shape but slowly, and are, in form, often like huge trees with spreading tops. The eruptive or metallic prominences, on the other hand, rush outward, with immense speed to gigantic heights, and change their shape and size with great rapidity. The velocity of their outward rush is in some cases as high as six hundred miles a second. They are most brilliant and fascinating objects, but are usually of short duration, seldom lasting over half an hour and are apparently composed largely of metallic vapours. Sometimes they spring into existence, flame up to prodigious height, and die out again, all within two or three minutes. They appear to be intimately connected with the formation of sun-spots, and are mostly found in the spot zones. Some of the masses of heated gas hurled from the eruptive prominences must, it is evident, pass beyond the solar control, since the Sun's attraction is unable to hold back any matter that started from its surface with a velocity greater than three hundred and eighty-three miles a second. Escaping into space, these masses would condense into solid bodies and speed away to regions unknown, an occasional one, perchance, finding its way to one of the planets.

The visible, bright surface of the Sun—the innermost portion that can be seen—is the "photosphere," or *light sphere.* It is a white cloud-like covering, composed largely of intensely hot metallic vapours, and from it comes most of the light and heat. It is considerably darker at the edge than toward the apparent centre of the disk, and to the naked eye appears relatively uniform and calm. In the telescope the entire

U. S. Naval Observatory, Washington

PLATE XXIII. Total Eclipse of the Sun, with Corona, May 28, 1900

surface has a granulated or mottled appearance, which has been aptly compared to that of a piece of grey cloth with rice-grains or snowflakes thickly scattered over it.

Above the seething photosphere lies the relatively quiescent "reversing layer," which is composed of glowing gases, and varies from five hundred to a thousand miles in thickness. It is somewhat cooler than the photosphere, and contains many of the terrestrial elements in a vaporous state. It was discovered by Young, by means of the spectroscope, during the total solar eclipse of 1870. Scattered through it, and close to the photosphere, is a thin cloud of small particles, which tends to reduce somewhat the intensity of the light radiated from the photosphere.

On the reversing layer rests the "chromosphere," or *colour sphere*, the upper portion of which is in a state of violent agitation, like the waves of the storm-tossed sea. Like the prominences which rise from it, the chromosphere is of a brilliant scarlet colour, but its redness is completely overpowered by the intensely white light of the photosphere shining through it. It is from five thousand to ten thousand miles in depth, and is made up mainly of incandescent hydrogen, helium, and calcium. As seen through a telescope, at a total solar eclipse, it has been aptly described as like "a prairie on fire." Like the prominences the chromosphere is observable at any time with the spectroscope.

Next in order, outside the chromosphere, lies the "corona," a halo of pearly-white light, observed only during the few minutes of totality of a solar eclipse, that streams out from the Sun to a distance of several million miles, and gradually loses itself in the dark

background of the sky. It forms a charming crown of glory to the eclipsed Sun, and is altogether a most beautiful and impressive phenomenon, a reminder of the nimbus or halo with which the heads of saints are encircled in works of art. Its shape varies in close accordance with the sun-spot period, and its light is about two or three times as great as that of the full moon.

Sometimes, as when appearing at the time of spot-maximum, it sends out rays and streamers in all directions, in a manner suggesting the rays of a mammoth star. At other times, as when appearing at spot-minimum, it shows two great wings sometimes of most extraordinary length, extending east and west in the direction of the Sun's equator, and a number of short, plume-like rays, or brushes of light, round the solar poles. The late Langley, in the clear air of Pike's Peak, traced the vast equatorial wings of the corona of 1878, with the naked eye, to nearly twelve million miles. It is apparently made up of particles of exceedingly rarefied matter mingled with incandescent gases, a characteristic constituent of which is an element, unknown on earth, called Young's coronium. According to Mendeléeff, this element—coronium—is supposed to be a very light gas, with a molecular weight and atomic weight about one-tenth that of helium.

In mythical story, the Sun was considered as the god of day—the Day Star—and was accorded divine honours. Its representative in the Greek pantheon was Helios, afterwards identified, though not completely so, with Phœbus Apollo, the Sun-god; and to the Romans it was known as Sol. Helios was the son of Hyperion and Thea, and a brother of Selene and Eos. He was described as the god who sees and hears everything, and

by Homer was alluded to as giving light both to gods and men. His symbol, fire, was maintained with the utmost care upon heathen altars. Moreover, so exceedingly wide-spread was sun-worship, that the idolatrous practice seems to have existed at some period in nearly every land. Among the animals particularly sacred to the Sun may be mentioned the cock.

Like the stars, the Sun was supposed to rise in the east, out of the River Oceanus, traverse the heavens in a glowing chariot, and descend into the darkness of the west and Oceanus, returning during the night in a winged boat of gold. Another legend relates that he inhabited a most magnificent palace, not far from Colchis, to which after his daily drive across the sky, he was conveyed in a golden boat along the northern coast of the Euxine, now the Black Sea. The horses and chariot with which he traversed the heavens are first mentioned in the Homeric hymn on Helios.

In the Vedas of the Hindus are hymns to the Sun, as also to the stars and the dawn, which formed a sort of ritual, that was chanted by the priests at sunset and sunrise. With the Egyptians the rising sun was Horus, the child-god, and the setting sun, Osiris, the husband of Isis. In the myth of Horus, as depicted on Egyptian temple walls, Horus was represented as battling with and slaying Typhon, the god of the underworld, who had cruelly murdered and mutilated his father Osiris.

Many of the solar temples of the Egyptians faced either the sunrise or the sunset, at the time of the summer solstice, while others were oriented to the winter solstice. And again, nearly all the Grecian temples were oriented so that the Sun might shine through them at some period of the year. The cathedrals of the Middle Ages were mostly oriented to the

sunrise. Furthermore, many of the old English cathedrals are found to face due east, or to the sunrise on the festal day of their patron saint. At Stonehenge (stone-circle) on Salisbury plain, about two miles from Amesbury, and ninety miles south-west of London, are the imposing ruins of an ancient sanctuary erected about three thousand years ago, and probably Druidical, where a single large rock appears so placed that as the Sun rises on midsummer's day (June 21st), its shadow falls on the central so-called altar.

The famous Colossus that stood at the entrance of the harbour of Rhodes was a statue to the Sun, by Chares, a pupil of Lysippus. It was erected B. C. 280, and was upward of 105 feet in height. It stood, however, only fifty-six years, as it was overthrown and broken to pieces by an earthquake B. C. 224. Nine hundred years after it had come crashing down, the Saracens cleared up the debris, and loaded nine hundred camels with the metal recovered.

In Peru the worship of the Sun constituted the peculiar care of the Incas. In the capital city Cuzco—the city beloved of the Sun—stood a magnificent temple with an image of the Sun emblazoned upon the western wall. The figure was engraved on a massive plate of gold, of enormous dimensions, thickly powdered with emeralds and precious stones. It was so situated that when the huge doors of the eastern portal were thrown open, the rays of the rising Sun fell full upon it.

CHAPTER IV

MERCURY AND VENUS

The planet Mercury, the fast-flying planet, is the smallest of the Sun's planet family, and has no satellite circling round it. There are recorded observations of it made nearly three centuries before the Christian era, although the ancient astronomers failed to recognise its identity, as it appeared alternately in the morning and in the evening sky. For a time it was supposed to be two independent planets, and to these, separate names were assigned. By the Greeks, the morning star was called Apollo, and the evening star Mercury. Later, however, when these were found to be one and the same body, the name Mercury became universally applied to it. As it is never more than twenty-eight degrees from the Sun, it is comparatively seldom visible to the naked eye, and then only when it is near one elongation or the other. As an evening star it is best seen at eastern elongations in the spring, and at western elongations in the autumn. Even at its greatest elongation, it is visible for only about an hour or two after sunset, or an hour or two before sunrise. At the most favourable time to view it—during the evening exhibit that happens in the spring—it will, for more or less than a week, if the sky is clear, be readily seen in the twilight from half an hour to an hour or more after

sundown. The eastern elongations for 1914 occur on February 22d, June 18th, and October 15th, and the western elongations on April 6th, August 5th, and November 23d.

When seen with the naked eye, Mercury sparkles in the sunset glow with a slightly reddish tint, and when viewed through the telescope at midday or late in the afternoon, its colour is about that of the Moon or lighter. It is the nearest known planet to the Sun, its average distance being only thirty-six million miles, or a little less than two-fifths that of the Earth. Its orbit is so eccentric that the actual distance of the planet from the Sun varies from twenty-eight and a half million miles at perihelion to forty-three and a half million miles at aphelion. Its distance from the Earth varies from forty-nine million miles at the most favourable inferior conjunction, to one hundred and thirty-six million miles at the most remote superior conjunction. Its period of revolution—its sidereal period, or true year—is about eighty-eight terrestrial days (87.97), and its mean synodic period (from one inferior or superior conjunction to the next) is about one hundred and sixteen days. The latter period is the more important of the two for observational purposes. The inclination of the planet's orbit to that of the ecliptic is about seven degrees.

Owing to the great eccentricity of its orbit, Mercury's speed varies from thirty-five miles a second at perihelion to only twenty-three at aphelion, so that its mean orbital velocity is about twenty-nine miles a second. The variations in its orbital velocity have the effect of bringing sometimes part of one edge, and sometimes part of the other edge of the dark hemisphere into the sunlight, and thus give rise to the phenomenon known

as *libration*. When the planet is nearest the Sun, it receives nine times as much light and heat as the Earth does, but when farthest away from it, only four times as much. In other words, it receives two and a quarter times more light and heat when nearest than when farthest from the Sun. Then, too, it makes the change from one position to the other within the comparatively short period of six weeks. Like Venus and the Moon, Mercury goes through phases from crescent to full. When nearest the Earth it is "new"; and when farthest away it is "full." At the two intermediate points of its planetary path, its appearance is not unlike that of the Moon at its first and third quarters. These phases, which are invisible to the naked eye, are readily observable in a small instrument.

The diameter of Mercury, which, until recently, was supposed to be not over three thousand miles, is actually thirty-four hundred miles. The mass and density of the planet are not known with any degree of accuracy, although its average density is believed to be somewhat less than that of the Earth—the densest of all the planets. Its mass is considered to be so small, however, and its gravitative power so weak, that in accordance with the kinetic theory of gases, it could not hold any molecule moving faster than about two and a half miles a second, and as the molecules of but few gases move thus slowly, one would not expect to find much, if any, atmosphere on the planet. It has the lowest albedo, or light-reflecting power, in the local solar system. It has been calculated that it reflects only about thirteen per cent. of the light it receives from the Sun, eighty-seven per cent. being absorbed, which shows a lack of clouds and suggests also a scarcity of atmosphere. Clouds, especially white clouds, form one

of the most highly reflecting surfaces known, giving out about seventy-two per cent. of the light that falls upon them.

While little, if anything, is known as to the surface conditions existing on Mercury, it is generally conceded that the planet's surface is rugged and mountainous, somewhat similar to that of the Moon. Its force of gravity is smaller than that of any of the other planets, being a little less than one-quarter that of the Earth. Hence a man weighing one hundred and fifty pounds on the Earth, would weigh only about thirty-six pounds on Mercury.

From a study of the faint markings noted upon it, the idea was announced in 1882, by the late Schiaparelli, and since confirmed by many observers, notably Lowell, that the planet rotates on its axis once during its revolution around the Sun. Consequently it keeps always the same side toward that luminary, as the Moon does toward the Earth, whilst its year and its day are of equal length, namely about eighty-eight terrestrial days. Roughly speaking, the temperature on the side that faces toward the blazing, dazzling Sun is over three hundred degrees above zero, while on the other side which is exposed to the intense cold of interplanetary space, it is more than four hundred and fifty degrees below. It has been estimated that about three-eights of the total surface will remain in perpetual darkness, and about four-eights in continuous sunlight, while, as a result of the planet's great libratory swing, the remaining one-eighth (a zone perpendicular to the equator and extending from pole to pole) will have alternately day and night, and perhaps something resembling a tolerable temperature. It is believed that the axis of the planet stands plumb to its orbit

plane, and that consequently it has no change of seasons such as the Earth enjoys.

When, as occasionally happens, an inferior conjunction occurs at the time the planet is near one of its nodes (points where its orbit intersects the ecliptic), it will appear to cross the Sun's disk, as the Moon does in solar eclipses. This phenomenon is called a transit of Mercury, and though of no great astronomical importance, is of no small interest to the amateur. During a transit the planet appears, when viewed in a small telescope, as a small, black, circular spot, against the bright solar surface. Since the Earth passes the line of nodes on May 7th and November 9th, transits can occur only near those days. They occur more frequently in November than in May, because Mercury is then much nearer the Sun. Their mean duration is about five hours. The first transit ever observed was that of November 7, 1631, by Gassendi. The last transit took place on November 14, 1907, and the next three will occur on November 7, 1914; May 7, 1924, and November 8, 1927.

By the mythologists Mercury was considered as a herald and messenger of the gods, and was called Hermes by the Greeks, and Mercurius by the Romans. The Greek Hermes was a son of Jupiter and Maia, the daughter of Atlas, and was one of the twelve great gods of Olympus. He was endowed with shrewdness and sagacity, combined with cunning and the inclination to lie and steal. A few hours after his birth, as the legend runs, he escaped from his cradle in a cave at Mount Cyllene in Arcadia, went to Pieria and carried off some of Apollo's oxen. Among other things, he is said to have run off with the sceptre of Jove, the sword of Mars, the trident of Neptune,

and the magic girdle of Venus. He was the patron of orators, merchants, tradespeople, travellers, and thieves, and conducted the shades of the dead from the upper into the lower world. Mercury was likewise the patron of all gymnastic games of the Greeks, and is said to have been the author of a variety of inventions. He was regarded as the maintainer of peace and as the god of roads. His attributes were a travelling hat with broad brim, a staff given to him by Apollo, and a pair of beautiful golden sandals, which carried him across land and sea with the rapidity of the wind. At the ankles the sandals were provided with wings. Among the things sacred to him were the tortoise, the palm-tree, and the number four.

In the seventeenth century, Goad, an old English writer, humorously termed the dwarfish planet, "a squinting lacquey of the sun, who seldom shows his head in these parts, as if he were in debt."

Venus

> Next Venus, matchless for her brilliant light,
> Seems as the lesser Cynthia of the night.
>
> BROWN.

The best known of all the planets is Venus, often called the Earth's "twin-sister." When near its extreme eastern or western elongation, it is the most brilliant and beautiful object in the heavens, the Sun and Moon excepted. Its dazzling, silvery light is often so intense that on moonless nights it casts quite a distinct shadow. Its brilliancy when at its greatest (Plate XXVIII.) has been estimated at about nine times that of Sirius, the brightest of all the stars, and five times that of Jupiter. It is ordinarily best viewed

in the twilight or just before dawn, when the faint light of day takes off from its glare.

It is extremely beautiful even in a good field-glass or prism binocular, and in an instrument equatorially mounted, can be readily seen in broad daylight. Like Mercury, it swings back and forth on either side of the Sun, and never departs far from that luminary, its farthest distance being forty-seven degrees. And again, it never gets higher in the heavens than forty-five degrees, which is half-way up to the zenith.

When east of the Sun, Venus may be seen in the western sky, and is an evening star; when west of the Sun, it rises before dawn, and appears in the eastern sky as a morning star. It shines as an evening star from superior to inferior conjunction for nine and a half months, and as a morning star from inferior to superior conjunction for about the same length of time, remaining, in either case, visible anywhere from seven to eight months. It reaches its greatest brilliancy some thirty-six days before and after inferior conjunction. At its greatest eastern elongation, it is visible for as much as three and a half hours after sundown, and at its greatest western elongation for about the same length of time before dawn. It will be in superior conjunction in 1914 on February 11th, and from the latter part of March to November will be the most brilliant and beautiful object in the western sky. Then, too, on August 5th, rather more than a month before greatest eastern elongation, it will pass within one-sixth of a degree of the planet Mars. Furthermore, it will be again at its best as an evening star in April, 1916, December, 1917, and July, 1919, and as a morning star in February, 1915, September, 1916, and April, 1918.

The ancients supposed Venus, the Mater Amorum,

to be two separate stars, calling it Phosphorus or Lucifer, when appearing in the morning sky, and Hesperus or Vesper, when appearing in the evening sky.

> Phosphor she's termed when morning beams she yields;
> And Hesp'rus when her rays the evening gilds.
>
> BROWN.

The identification of Hesperus with Phosphorus is supposed to have been first made by the celebrated sage of Samos, Pythagoras. It is said that the Basutos still differentiate the morning and evening Venus. In a two-inch telescope Venus, like Mercury, exhibits phases (Fig. 7.), appearing, when farthest from the Earth, like the full moon, then gibbous, then like a half moon, then as a crescent, and finally, when nearest to the Earth, like the new moon. Its synodic period covers nearly 584 days, or rather less than one year and four months. The corresponding sidereal period, or true year of the planet, is a little less than 225 days (224.7), or not quite two-thirds as long as the terrestrial year.

The average distance of Venus from the Sun is 67,200,000 miles. Its orbit is more nearly circular than that of any other planet, the eccentricity (0.0068) being so small that the difference between its greatest and least distance from the Sun is less than a million miles. When nearest to the Earth, it is approximately twenty-five million miles away, but when at its greatest distance, owing to the situation of the two bodies in their orbits, it is somewhat over 135 million miles farther off. It has an orbital velocity of twenty-one miles a second, and, like Mercury, has no satellite. Its diameter is 7630 miles, or not quite three hundred miles less than the Earth's diameter. It is a more perfect

sphere than is the Earth, being very little flattened at the poles, or bulged at the equator. Its mass is about 0.82, its density about 0.89, and its surface gravity about 0.86 that of the Earth. Being so much nearer the Sun it receives nearly twice (1.9) as much solar light and heat as does the Earth. It reflects about seventy per cent. of the light which falls upon it, or about the same as that reflected by newly fallen snow. It has been estimated that its atmosphere is about twice as dense as that of the Earth, and full of clouds. Moreover, the peculiar brilliancy of Venus is thought by many to be, in great part, due to its cloud-laden atmosphere. Lowell and some others, however, deny that Venus is a cloud-wrapped planet, and consider that it owes its great lustre largely to its not being cloud-covered. Its gravity is such that no molecule of gas coming within the influence of its attraction, and travelling with a less speed than 6.37 miles a second, can escape from it.

Concerning the rotation time of Venus, opinions differ greatly. Until about twenty-five years ago, it was generally supposed that both it and Mercury rotated on their axes in a period approximately twenty-four hours long. Now, while some astronomers, notably Trouvelot, Bélopolsky, and See, still hold that it spins around in about twenty-three hours and twenty-one minutes, other observers, including Schiaparelli, Perrotin, and Lowell, believe that, like Mercury, it turns on its axis in the same time that it revolves about the Sun. In the former case, the day would be only a little shorter than the terrestrial day, and in the latter it would be equal to the planet's year. While the question must still be considered as an open one, and far from being definitely set-

20

eighteen and one-half miles a second, or about one and a half million miles a day. On account of the eccentricity of its orbit, which amounts to not quite one-sixtieth (0.016), it is some $3\frac{1}{10}$ million miles nearer to the Sun in winter (in the northern hemisphere) than in summer, and moreover the Sun looks nearly two per cent broader than when at its greatest distance. The planet's mean density, taken through and through, compared with that of water, is found to be about 5.53. At the Earth's centre the density must be much greater than at the surface, equal probably to that of the heavier metals.

The total mass of the planet has been estimated as equivalent to a weight of about sixty-five hundred million million million tons, and its age has recently been stated by Chamberlin to be not less than four hundred million years. Up to a comparatively recent date it was quite generally supposed that the Earth's interior must be in a molten state, owing to the high temperatures existing there. Now, however, scientific men believe that the Earth as a whole is more or less solid throughout, except perhaps in isolated places where collections of molten matter may exist. Furthermore, it is thought that it has a rigidity, when considered in its entirety, twice as great as that of steel. According to Sollas, the mean rate of rise of underground temperatures is about 1° F., for every 80 or 90 feet of descent. It varies greatly, however, at different places. In the Calumet and Hecla Mine, Lake Superior, which is 4989 feet in depth, the rate varies from 1° F. in 103 feet to 1° F. in 95 feet. The deepest boring is that made by the Austrian Government in Silesia, and is a mile and a quarter in depth. From these and other estimates, taking even the lowest rate

of increase of temperature, it is apparent that if it continues to great depths, the temperature of the interior must be very high. And yet, as the pressures on the earth's interior are presumably enormous, it is justifiable, without stretching probability too far, to assume that they tend to keep the matter in a solid state in spite of the high temperature. It has been calculated that the pressure at the centre of the Earth is equivalent to three million times the pressure of the atmosphere at the Earth's surface, or about forty-five million pounds to the square inch.

The terrestrial surface contains about 197,000,000 square miles and is divided into two wide areas of land and water, of which about one-fourth is land and about three-fourths water. The northern hemisphere contains about three times as much land as the southern, and the eastern hemisphere about two and a half times as much as the western. Like the face of the land, the bed of the ocean is marked by elevations and depressions, for it has its mountains and valleys, as well as its plains and plateaus of grey ooze. The difference between the average height of the continents and the average depth of the oceans is about three miles. The plateau of Tibet is about three miles above sea-level, and the bottom of the great Tuscarora Deep is about five miles below sea-level, making a difference in range of eight miles.

The apex of the loftiest known mountain, Mount Everest in the Himalayas, is 29,002 feet above sea-level, and the bottom of the deepest ocean pit, about forty miles off the north coast of Mindanao, one of the Philippine Islands, is 32,086 feet below sea-level, making a difference in range—the greatest known—of over eleven and a half miles. It has been calculated

by Chamberlin and Salisbury, that were all the continents rubbed down, and all the oceans silted up, so that the Earth was a perfectly smooth ball, it would be covered everywhere by its waters to a depth of nearly two miles. And again, geologists estimate that the general shrinkage of the planet, which they believe is going on, carrying down land surface and sea-bottom, has resulted in lessening its radius by some thirty-two miles.

Surrounding the spinning Earth is a gaseous envelope of limited depth called the air, or the atmosphere, which is held to it by gravitation, and rotates together with it, and upon the presence of which nearly all forms of life on earth depend. Roughly speaking, it is made of nitrogen and oxygen, together with small quantities of other elements, such as argon, neon, xenon, krypton, and helium, and some compounds such as carbon dioxide and water vapour. About one-fifth by volume is oxygen, three-fourths nitrogen, three- or four-hundredths of one per cent. carbon dioxide, and a variable proportion water vapour. It is densest near the surface of the Earth and becomes less and less dense away from it, the density at a height of three and a half miles being approximately one-half that at the surface. Moreover, it seems that for every three and a half miles of ascent, the density of the atmosphere divides by two. The atmospheric strata have been compared by Shaw to the coats of an onion, and Rotch has shown that, at a height of several miles, there is a layer called a "reversing layer," where temperature ceases to fall with increasing height.

Although it is impossible to determine exactly where the Earth's atmosphere ceases, there are reasons for believing that it may extend as far as one hundred

to two hundred miles, and beyond that can be said practically not to exist. Theoretically, however, its height is much greater, as in all probability it does not entirely cease to exist till the limits of the Earth's gravitative influence, some 620,000 miles off, are passed. In the thin height of the terrestrial atmosphere, any gas molecules flying upwards with a velocity greater than $6\frac{25}{100}$ miles a second will pass beyond the limits of the Earth's attraction and never return. And again, any wandering molecules of gas journeying through the solar system, which happen to come within the limits of the Earth's influence, will be captured by the planet. In this connection it may be noted, however, that as the molecules of nitrogen and oxygen, which enter largely into the composition of the atmosphere, move with a velocity[1] far below that necessary for escape from the Earth, there is no danger of the Earth's losing its aërial envelope rapidly.

The weight of the atmosphere, as calculated by the late Mendeléeff, is fifty-one hundred billion tons. Its pressure at sea-level is about $14\frac{7}{10}$ pounds to the square inch. Hence, on the body of an adult person, averaging some two thousand square inches of surface, the pressure amounts to about fifteen tons. The air is a common medium of sound transmission, sounds being any vibrations that are capable of being perceived by the ear. The velocity of sound in the air at the temperature 32° F. is 1090.5 feet a second, and the increase in velocity due to rise in temperature is $1\frac{1}{10}$ feet for each degree of Fahrenheit. The velocity of sound in liquids is over four times as great as in air, and in solids from eleven to fifteen times as great.

[1] The maximum velocity of the molecules of oxygen is 1.8 miles a second, that of nitrogen 2 miles, and that of water vapour 2.5 miles.

it does not catch the heat which the Earth is radiating, and in consequence the temperature drops more rapidly and to a lower point.

To the rotation of the Earth on its axis from west to east, once in about twenty-four hours, is due the phenomenon of day and night, while to the Earth's revolution around the Sun, and the inclination of its axis to its orbit, which is twenty-three degrees and twenty-seven minutes, are due the variations of the seasons, and the differing lengths of day and night in various parts of the globe. Moreover, in Holy Writ is the assurance that "while the Earth remaineth, seed-time and harvest, and cold and heat, and summer and winter, and day and night, shall not cease" (Genesis viii., 22).

About the 21st of June, the summer solstice, the northern hemisphere is tilted toward the Sun at its greatest inclination, and the period of longest daylight occurs. At this time the Sun rises and sets north of the east and west points, is high in the heavens, and at this latitude remains over fifteen hours above the horizon. It is now midsummer in the northern hemisphere, and midwinter and the shortest day in the southern. After the solstice is past, the Sun begins to descend toward the equator, but as the amount of solar heat received during the day is greater than that radiated away at night, the mean temperature continues to rise. Owing to this more or less steady temperature increase, which may be prolonged for some six weeks, the hottest days of summer are not experienced until about the latter part of July or early in August. At the autumnal equinox on the 23d of September, the axis of the Earth is upright relative to the Sun, which now crosses the equator, and there is equal day and night

all over the world. The Sun rises and sets exactly in the east and west points, rising at 6 A.M. and setting at 6 P.M. It is now autumn in the northern and spring in the southern hemisphere.

After the autumnal equinox, the northern hemisphere tilts more and more away from the Sun, which sinks each day lower and lower towards the southern horizon. About the 22d of December, the time of the winter solstice, the Sun reaches its greatest southern declination, and the northern hemisphere is tilted from it at its greatest tilt. The Sun rises and sets farthest south of the east and west points, and the shortest day in the year takes place. It is now winter in the northern hemisphere and summer in the southern. At the South Pole it is mid-day of the long six-months' polar day, and at the North Pole it is midnight of the long six-months' polar night. About the 31st of December, the Earth reaches its perihelion, and is then nearest the Sun, being about $3\frac{1}{10}$ million miles nearer to it than in midsummer. The period of greatest cold in the northern hemisphere does not occur when the days are shortest, but some six weeks later, namely about the end of January or beginning of February, as the Earth continues for a time to lose more heat during the night than is received during the day.

After the winter solstice, the days gradually increase in length and the Sun rises at noon each day higher in the heavens, until about the 21st of March—the vernal equinox—it is overhead at the equator, and day and night are again equal all over the Earth. The Sun at this time rises exactly in the east and sets exactly in the west. It is now spring in the northern hemisphere and autumn in the southern. After the vernal equinox, the northern hemisphere becomes more and more tilted

toward the Sun, which continues its northerly course, mounting higher and higher in the sky, until it arrives again at its greatest distance north of the equator about the 21st of June. The Earth in the meantime is receiving more heat than is lost by radiation, the temperature steadily rises, and gay summer begins.

Owing indirectly to the eccentricity of the Earth's orbit, the seasons in the northern and southern hemispheres are of different length. The summer half of the year (from the vernal to the autumnal equinox) in the northern hemisphere is 186½ days, and the winter half of the year (from the autumnal back to the vernal equinox) is 179 days. In other words, the summer half of the year is 7½ days longer than the winter half. The conditions are reversed in the southern hemisphere, the winter half of year being longer than the summer half. Furthermore, the winters are colder, and the summers hotter, in the southern hemisphere than they are in the northern.

The precession of the equinoxes, as previously noted, causes the axis of the Earth to swing slowly round westward in space, while at the same time, the attraction of the other planets slowly changes the position of the Earth's orbit, in such a way that the apsides (the aphelion and perhelion points) move round slowly eastward. By reason of the combination of the precession with the motion of the apsides, a revolution is produced, which will in the course of time (about 10,000 years) reverse the present state of things. The perihelion will then be reached in June and the aphelion in December. The northern summer will then be the shorter and the hotter one, and the northern winter the longer and the colder one.

In mythology the Earth was personified under the

name of Gæa or Ge. In Hesiod, Gæa (Terra) is the first being that sprang from Chaos, and gave birth to Cœlus, or Uranus, the first ruler of the world.

> Ere earth and sea and covering heaven were known,
> The face of nature, o'er the world, was one;
> And men have call'd it Chaos.
>
> OVID (Elton's tr.).

Ge was called the wife of Uranus, and the mother of the Titans, the Giants, the Cyclops, etc. Uranus hated these children, and Ge (Terra) therefore concealed them in the bosom of the Earth. She made a large iron sickle, and gave it to her sons, requesting them to take vengeance on their father. Cronos (Saturn) undertook the task and mutilated Uranus. The drops of blood which fell from him upon the Earth (Ge) became the seeds of the Erinyes, the Gigantes, and the Melian nymphs. Ge belonged to the deities of the nether world. Her worship appears to have been universal among the Greeks. Temples and altars were dedicated to her in almost every Greek city and in Rome.

Pio Emanuelli of Rome has recently determined, from astronomical conditions, that the Crucifixion of Jesus Christ took place on the 7th of April, 1885 years ago. According to the most authentic records the date of our Lord's birth was about 4 B.C., and He only lived to be thirty-three, but the wondrous things He did during his brief stay here will be with the world through the ages.

The Tides

The tides are the periodic changes in the level of oceanic and other large bodies of water, caused mainly-

by the gravitational pull of the Sun and Moon as the Earth rotates upon its axis. The Moon, being so much nearer the Earth than is the Sun, exerts the stronger pull, and plays the chief part in the raising of the tides, the tide-raising force[1] of the Sun being only about five-elevenths that of the Moon. The tides ebb and flow generally twice every twenty-four hours and fifty-one minutes, a time identical with the interval between two successive passages of the Moon over the meridian. Hence the average interval between two successive high or low tides is about twelve hours and twenty-five minutes, and the average retardation from day to day is about fifty minutes. The time of high water occurs, not at the exact moment of the Moon's meridian passage, but a certain number of hours and minutes later, the length of the interval varying with the place of observation. The average interval between the time of meridian passage of the Moon and the time of high water is known as the "establishment of the port" (*l'établissement du port*). The establishment for New York is eight hours and thirteen seconds, and, therefore, the time of high water each day will be, on the average, eight hours and thirteen minutes later than the time given in the almanac for the passage of the Moon across the meridian.

Every lunar month there are two especially great tides known as Spring Tides, and two especially little tides known as Neap Tides. Spring tides—the highest tides of the month—occur within a day or two of the time the Moon is either new or full, when it and the Sun are both exerting a pull in the same straight line.

[1] The tidal force exerted by any celestial body, it should be remembered, varies inversely as the cube—not as the square—of its distance, and directly as its mass.

Neap tides—the lowest tides—take place when the Moon is near first and third quarters, at which time the Sun and Moon are tending to pull the waters in different directions. The relative heights of spring and neap tides are about as eight to three. When the Moon is nearest the Earth, the tides are almost twenty per cent. higher than when it is at its greatest distance. The tides are also higher than usual about the vernal and autumnal equinoxes, being highest near the autumnal equinox. The lowest tides occur at the solstices, the tides of the summer solstice being lower than those of the winter ones. The age of the tide at any place refers to the interval from the time of the new or full moon to the time of the next spring tide; while the difference in height between a high and a low tide, at any particular place, is called a range of tide.

The tide consists of two parts—the direct tide upon the portion of the globe lying just under the body giving rise to it, and the opposite tide situated on the contrary side of the Earth—the waters on the near side of the Earth being affected by the tide-generating forces more powerfully than is the Earth, and the Earth in general more powerfully than are the waters on the far side of the earth. As the Earth rotates on its axis the watery bulge, or protuberance, appears to travel from east to west as a tidal wave twice in twenty-four hours and fifty-one minutes, each wave differing slightly from its predecessor. In accordance with the laws of wave motion, the form of the wave only—not the water of the ocean—travels, while the speed of the wave depends upon the depth of the water. The average depth of the ocean is about three miles, and in each ocean is produced its own individual tidal wave. Once formed,

these waves travel from ocean to ocean, and meeting other waves, more or less modify the tides.

The great or parent tidal wave originates in the deep waters of the Southern Pacific, off Callao in Peru. It spreads east and west around Cape Horn, and past the Cape of Good Hope, having during its broad sweep combined with a small tide-wave from the Indian Ocean. Here it joins the tide in the Atlantic off the African coast, and a small wave which has backed into the Atlantic around Cape Horn. The resultant wave sweeps northward up through the Atlantic with a velocity of about seven hundred miles an hour, being forty-one or forty-two hours old when it reaches New York. It is nearly sixty hours old when it reaches London and the German coast, having had to pass along the western coasts of Ireland and England, around the northern end of Scotland, and through the North Sea. Thus in the great oceans, there must be at least five or six tide crests travelling simultaneously, following each other over nearly the same track.

The time and character of the tides are affected by winds, by the contour of the land, and the depth of the sea. In mid-ocean the tides are only about two feet high. On the Long Island coast they are not over three feet in height, while on the coast of Maine their average height is from ten to twelve feet. In Long Island Sound the conditions are such that the wave motion produces a rapid current, the rise and fall of the tide being about seven feet. The greatest tide in the world is to be seen in the Bay of Fundy, where tides of seventy to one hundred feet are said to be not uncommon, their average height being about sixty feet. In lakes and inland seas, the tides are small and difficult to detect. The Mediterranean and Baltic seas

have very trifling elevations, the tides on the coast of the former averaging less than eighteen inches, although at the head of some of the gulfs it reaches the height of three or four feet. In Lake Michigan, a tide of nearly two inches has been detected, the "establishment" of Chicago being about half an hour.

According to the view of the late Sir George Darwin the constant tidal wave acts as a brake, and tends to slow down the speed with which the Earth rotates on its axis, and to lengthen the day. To-day the friction between the waters and the Earth, which retards the tides and diminishes the velocity of the Earth's rotation, is very small, and the consequent lengthening of the day and month extremely minute. So far as is known, the day is not lengthening by even so much as the hundredth part of a second in a thousand years. There are grounds for assuming, however, that tidal friction will, in the course of millions of years, so slow down the rotation of the Earth on its axis, that the day and the month will be equal, the planet then rotating on its axis in fifty-five of its present days. When that time arrives, the Moon will remain stationary over a certain spot of the Earth, and the two bodies, though still revolving around their common center of gravity, will turn the same face to each other.

Sidereal and Mean Time

So accustomed is every one to the apparent motion of the Sun around the Earth from east to west, that the real motion of the Earth around its axis from west to east, which produces the phenomenon, is often forgotten. As time is usually thought of as reckoned westward from the meridian, while right ascensions

are reckoned eastward from the vernal equinox—the intersection in the sky of the equator and the ecliptic —it may help to a clearer understanding of their relations, if the real motion is reverted to.

As suggested by Herschel, the extended plane of the meridian may be considered as a mammoth clock-hand or index-finger, and the celestial sphere as a great dial set with diamond stars for "time-marks," while the index-plane, revolving uniformly with the Earth from west to east, may be regarded as pointing to the successive marks on the heavenly dial. For further convenience other time-marks may be assumed, set along the celestial equator, among the stars, at equal distances from each other. Adopting a starting point for these, the whole circle may be divided into 360 equal parts called degrees, or into twenty-four equal parts called hours. And as the natural time-marks cannot always be seen, and not at all the artificial ones, and the index cannot always be extended, a machine has been invented, called a clock, that shows in effect the several equal intervals as marked out and indicated by the terrestrial index, on the artificial celestial equatorial dial.

The vernal equinox or first of Aries—the noon-mark for sidereal time—is such a starting point. The interval between two successive returns of the meridian index plane thereto is called a day—a *sidereal* day—and each of its twenty-four equal parts, counted from 0 to 24, a sidereal hour, and the clock a sidereal clock, while the duration reckoned in these units is termed sidereal time. The position of the natural time-marks, namely, the Sun, Moon, planets, and fixed stars, relative to the artificial time-marks, have been carefully tabulated, and the sidereal times they indicate are called the right ascensions of these bodies.

For other uses the most natural time-mark, the Sun, may be adopted as a starting point. Here, however, it is quickly found that no clock that could be made would "keep step" with it. In other words it would be found that its days are not of equal length—that the Sun is in fact a poor time-keeper—the inequality being due to the variable orbital motion of the Earth, and the obliquity of the ecliptic. For instance, such a day near December 22d is $51\frac{2}{10}$ seconds of sidereal time, longer than a like day near September 17th. To avoid this inconvenience, a fictitious sun, known usually as the *mean* sun, has been adopted as a starting point. This mean sun is assumed to move uniformly along the celestial equator, sometimes ahead and sometimes behind the real or true Sun, but never more than about sixteen minutes (16 min. 18 sec.) from it in time, so that the interval between two consecutive returns of the meridian index or noon line to this mean sun shall be equal. Such days are called *mean solar days*,[1] and the twenty-four equal parts of them, *mean solar hours*, while duration reckoned in these units is called *mean solar time*, and the clock a *mean solar clock*. All ordinary clocks, it may be noted, are set to follow the fictitious or mean sun, the solar day being the actual day in ordinary use. Before clocks were perfected the gnomon and dial were used to give apparent solar time.

The earliest mention of a sun-dial is found in Isaiah xxxviii., 8: "Behold I will bring again the shadow of the degrees, which is gone down in the sun-dial of Ahaz, ten degrees backward." The largest sun-dial on record —the so-called "prince of dials"—is that at the modern

[1] There is also a planetary day, a lunar day, and a star day, which in length is the same as a sidereal day, within one-hundredth of a second.

Hindu city, Jaipur. It was built about the middle of the eighteenth century by the famous Mahárájá Siwái Jái Singh II., and restored in 1902. Its gnomon, with stone stairs, is nearly 150 feet long at its base, and about 90 feet in height. The dial is so arranged that the shadow of the gnomon falls on a large stone quadrant of 50 feet radius, across which, as noted by Jacoby, it moves at the rate of 2¼ inches a minute.

In length, twenty-four hours of mean solar time are equal to 24 hrs. 3 min. and 56.55 sec. of sidereal time, and hence the solar day is nearly four minutes longer than the sidereal day. It has been conjectured, somewhat fancifully, that about forty-five million years ago, the day was but sixteen hours long; some ten million years before that only ten hours; and still earlier possibly not over one hour.

Whenever the meridian index in its revolution with the Earth arrives at the true vernal equinox, it is then said to be *sidereal noon* at all places on that meridian, or local sidereal noon to distinguish it from Greenwich sidereal noon. And the right ascension to which the meridian index, continuing its revolution, points at any instant, is called the sidereal time, or more definitely the local sidereal time at that instant at that meridian, to distinguish it from the Greenwich sidereal time at the same instant. Evidently, if the meridian index arrives at the Sun or a star or other celestial body, the local sidereal time of that event is just the right ascension of that body or point without further computation. The sidereal clock conveniently dispenses with direct observation of the sidereal dial.

Similarly when the meridian index, in its revolution, arrives at the mean sun, that instant is called *local mean noon*, to distinguish it from Greenwich mean

noon for which instant many of the quantities in the *Nautical Almanac* are tabulated. And the point on the artificial mean-time dial, to which the mean-time index, continuing its revolution, points at any instant, is called the *local mean time*, at that instant, to distinguish it from the Greenwich mean time at the same instant. The mean-time clock conveniently dispenses with direct observation of the mean-time dial.

These two time systems are so related that if the starting points were placed together the two dials would coincide, and any hour mark on either dial would exactly coincide with the like mark on the other, throughout the whole extent of both dials. Indeed this entire coincidence occurs once a year, about March 21st, namely, at the instant the mean sun, the initial point of one dial, is at the true vernal equinox, the initial point of the other dial. At that instant the two clocks also coincide. But only at that instant, for the mean sun, moving east, uniformly (sensibly so) increases its distance from the vernal equinox, that is its right ascension. It is as if the mean-time dial, concentric with the sidereal dial, revolved with its various time-marks, each advancing uniformly in right ascension equally with the mean sun, from which it is reckoned, at the rate of nearly four minutes a day. And this is also shown by the two clocks, the sidereal clock gaining that much on the mean-time clock each day, the difference amounting to exactly one day each year.

Reverting now to the relation between apparent or sun-dial time and mean solar time, it may be noted, that the difference between the two is called the "equation of time." On four particular days in the year, namely, April 15th, June 14th, September 1st, and December 24th, no difference exists between the clock and

the Sun. On these days the Sun comes to the noon-mark on the sun-dial precisely at twelve o'clock, and the equation is zero. At four other dates the difference is appreciable. Thus, the Sun is 14 min. 27 sec. behind the mean-time clock on February 11th; 3 min. 49 sec. ahead of it on May 14th; 6 min. 16 sec. behind it on July 16th; and 16 min. 18 sec. ahead of the clock on November 2d.

According to the system of standard time introduced in 1883, five standard times are in use in North America, viz., the colonial, the eastern, the central, the mountain, and the Pacific. These correspond severally to the mean local times of the 60th, 75th, 90th, 105th, and 120th meridians west of Greenwich, and are exactly four, five, six, seven, and eight hours slower than Greenwich time. Chicago is about one hundred miles east of the 90th meridian west of Greenwich, which runs through St. Louis, so that standard time at Chicago is about eight minutes slow.

The astronomical day is made to begin at mean noon, the hours being counted uninterruptedly from 0 to 24. The civil day, on the other hand, begins at midnight and ends at midnight, mean solar time, and is usually counted in two series of twelve hours each, although in some countries it is reckoned around through the whole twenty-four hours. In the early Scriptures of the Old Testament, the reckoning was from one setting of the sun to the next, "the evening and the morning" marking the day.

Were a traveller to start at any place, and go in a westward direction around the Earth, he would find the Sun crossing his meridian later each day, and in making the complete circuit he would lose exactly one day. On the other hand in going eastward around the Earth he would find the Sun crossing his meridian earlier each day, and in making a full circuit he would gain a

day. Evidently then, when going all the way around the earth in a westward direction, he must somewhere set the date forward a day, as from Tuesday to Wednesday, and in going around eastward, he must drop back a day in his reckoning, as from Wednesday to Tuesday. A convenient place to make the change of date, agreed upon by all civilised nations, is a hypothetical line coinciding approximately with the meridian 180° from Greenwich. This line is called the "international date-line," and passes through the western part of the Pacific Ocean, hardly anywhere touching the land. It is practically the place where each calendar day first begins.

Next to the day, the shortest natural division of time is the month—the period required by the Moon to make a revolution around the Earth. The time it takes the Moon to pass round the Earth from a given star to the same star again is called the *sidereal* or true month. Its length is, on the average, 27 days, 7 hours, 43 minutes, and 11.55 seconds, but it varies some three hours. On the other hand, the time occupied in passing from the phase of new or full moon round to the same phase again is called the *lunar* or *synodical* month. Its average length is 29 days, 12 hours, 44 minutes, and 2.86 seconds, but it varies nearly thirteen hours. It is a little more than two days longer than the sidereal month, and constitutes what is ordinarily understood as the *month*. The number of days in the month is tersely given in the following well-known jingle:

> Thirty days hath September,
> April, June, and November,
> All the rest have thirty-one,
> February has twenty-eight alone;
> But Leap Year coming once in four—
> February's days are one day more.

The period of time required by the Sun to complete its apparent circuit of the heavens, eastward in the ecliptic, from a certain place among the stars back to the same place again, is called the *sidereal* year. Its length, in mean solar time, is 365 days, 6 hours, 9 minutes, and 8.97 seconds, or a little over 365¼ days. The time taken by the Sun to pass from the vernal equinox around the ecliptic and back again to the vernal equinox is called the *tropical* or mean solar year. Owing to the precession of the equinoxes, the vernal equinox shifts slowly westward each year, so that the tropical year is about twenty minutes shorter than the sidereal year. Its actual length, in mean solar time, is 365 days, 5 hours, 48 minutes, and 45.51 seconds. To avoid the difficulty presented by the tropical year, as the number of days it contains is not an even one, the civil year or the calendar year has been instituted, having an average length almost exactly equal to that of the tropical year.

The early Greeks used a calendar based entirely upon the Moon, Hesiod describing the year as consisting of twelve months of thirty days each. The basis of the present calendar was fixed about the year 46 B.C., when Julius Cæsar, with the aid of the Alexandrian astronomer Sosigenes, established what is known as the Julian calendar. According to this calendar, the year consisted of exactly 365¼ days. Intent on getting rid of the quarter day, Cæsar ordained that it should be omitted from the reckoning for three years out of every four, and that every fourth year should contain 366 days, the extra day—made up of the four quarter days—being added at the end of February. The average year of the Julian calendar was, however, a little too long, being about 11 minutes and 14 seconds longer than the tropical year. Hence by the middle of the

sixteenth century the calendar had become in error by more than ten days. Pope Gregory XIII., therefore, in 1582 A.D., under the advice of the astronomer Clavius, introduced a slight change. The ten accumulated days were dropped outright from the calendar, and the 5th of October was styled the 15th. To prevent recurrence of the error, it was agreed that thereafter those years whose date numbers are divisible by four without a remainder are leap years, unless they are century years, and further that such century years as are exactly divisible by four hundred are also leap years.

In *The Climbing Boy's Soliloquies*, James Montgomery thus quaintly alludes to the onward movement of Time:

> Time, on his two unequal legs,
> Kept crawling round the church clock's face,
> Though none could see him shift his pegs,
> Each was forever changing place.

CHAPTER VI

THE MOON

How like a queen comes forth the lovely moon,
Walking in beauty to her midnight throne!

CROLY.

AFTER the Sun, the most important of all the heavenly bodies to the inhabitants of the Earth is that orb of reverie and mystery, "which gods Selene name, and men, the Moon," Earth's nearest neighbour in space and most faithful attendant. Owing to the variety of its phases and the more rapid changes of its relative position in the sky, it holds a unique position in the starry heavens, while in brightness it far outshines all the planets and all the stars. To an observer on one of the nearer planets the Earth and Moon must look not unlike a beautiful double star, the Earth seeming far brighter than Venus, and the Moon brighter than Jupiter. Furthermore, did lunarian inhabitants exist, the Earth would appear to them as a resplendent globe, from thirteen to fourteen times as large as the Moon appears to people on the Earth.

The mean or average distance of the Moon from the Earth is 238,840 miles. Owing to the eccentricity of its orbit (0.05) it is sometimes 252,972 miles away, and sometimes only 221,614. According to the latest measurements, the diameter of the Moon is 2163 miles,

Paris Observatory

PLATE XXIV. The Moon at Nine Days

(Image inverted as in astronomical telescopes)

or rather more than one-quarter that of the Earth. Its apparent diameter is about half a degree, or nearly the same as that of the Sun, although it varies somewhat, owing to the influence of the Earth's atmosphere. It travels eastward around the Earth in an orbit whose circumference is about 1,500,680 miles, at an average velocity of 2290 miles an hour, and completes a circuit in 27 days, 7 hours, 43 minutes, and 11.15 seconds, which, as mentioned in the preceding chapter, constitutes a sidereal month, the average length of the common or synodical month being 29 days, 12 hours, 44 minutes, and 2.86 seconds. Then, too, as the Moon moves around the Earth, it appears to travel around the sky among the stars, at the rate of about thirteen degrees a day.

The mean density of the Moon is about three-fifths that of the Earth, and its mass rather less than one-eightieth, while the force of gravity at its surface is about one-sixth that at the Earth's surface. It makes one rotation on its axis in the course of one revolution in its orbit, and in consequence, roughly speaking, it always keeps the same face towards the Earth. There is, therefore, one hemisphere of the lunar surface on which in its entirety no human eye has ever gazed. The collective effect, however, of the Moon's librations —the libration in longitude, the libration in latitude, and the so-called diurnal libration—is such that about four-sevenths of the lunar surface can be seen, while three sevenths remains forever concealed from view. Since the surfaces of globes are proportional to the squares of their diameters, and their volumes proportional to their cubes, it follows that the surface area of the Moon is about one-fourteenth, and the volume or bulk one-forty-ninth, of that of the Earth. The total surface

of the Moon is, therefore, about equal to the combined areas of North and South America, while the face which it always keeps toward the Earth is slightly greater in area than the Russian Empire.

The lunar globe is found to be devoid of any bodies of water, and is without sensible atmosphere. Indeed, it has not sufficient gravitative power to permanently retain an atmosphere, inasmuch as the critical velocity with which a particle would have to move in order to escape from the control of the Moon is only one and a half miles a second. With no atmosphere there is nothing to temper the alternate changes either from light to darkness, or from heat to cold. The day side of the Moon is exposed to the Sun's intense heat for a fortnight at a stretch, the temperature rising very high, probably reaching the boiling point, whilst through the long lunar night of a fortnight, the surface freezes in the icy cold, the temperature of the night side of the Moon falling very low, perhaps to 200° or 250° below zero. It is evident therefore, as another has suggested, that people not enjoying extremes of temperature should shun a lunar residence.

The amount of light and heat received from the full moon is estimated as not more than one-six-hundred-thousandth of that received from the Sun. Hence it is apparent that were the sky full of moons, the light received from it by the Earth would be only about one-eighth part of the Sun's light. That the lunar globe is an arid waste, an effete and soundless world, there is every reason to believe, and, furthermore, there is nothing to show that life in the form it exists on earth ever had its being amid that universal ruin. The most conspicuous services rendered the Earth by the Moon are the giving of light by night, and the raising of the tides.

Yerkes Observatory

PLATE XXV. The Full Moon; the Moon at Fourteen and One-Half Days

(Image erected; as viewed with the naked eye, opera-glass, or field-glass, or with telescope using terrestrial eyepiece. Some of the larger craters and chief mountain ranges are well shown here. The prominent crater in the lower right-hand quadrant of the illuminated disk is Tycho, and the large crater slightly below and somewhat to the left of the center of the disk is Copernicus. Note especially the wonderful system of bright streaks radiating from Tycho, and the complicated system of ridges and streaks radiating from Copernicus.)

Then, too, as indicated in Scripture, an important function of this silver orb of night is to regulate the calendar, and mark out the times for the days for which special ordinances were imposed. In the words of that noble nature-psalm for Whitsunday—the 104th Psalm:

> He [God] appointed the moon for seasons.

The ancient Hebrews had three great festivals, all defined as to the time of their celebration by the natural months, determined by actual observation of the new moon. The first was the Feast of the Passover, a spring feast, which corresponded to Easter in the Christian Church; the second was the Feast of Pentecost, that is, Whitsuntide; and the third was the Feast of Tabernacles, an autumn festival, which was held at the time of the "harvest moon." The only great festival in Christian countries that depends directly upon the monthly motion of the Moon is the festival of Easter, marking the anniversary of the resurrection of Christ. This festival is also affected by the apparent yearly motion of the Sun, since its date is governed by the vernal equinox. The dates of all other movable feasts depend on that of Easter. In accord with the decree of the Council of Nice, Easter Day is always the Sunday immediately following the first full moon—the paschal moon, as it is called in the calendar—which occurs on or next after March 21st, which is the regular date of the equinox. If the full moon happens on Sunday, Easter is celebrated one week later. The earliest possible Easter date is March 22d, if a full moon falls on March 21st and that day is Saturday, but this will not occur again till 2285. The latest possible Easter date is April 25th, if a full moon falls on March 20th, and the

next on April 18th and that day is Sunday, but this will not occur again till 1943. Easter happened to fall in 1913, near the extreme, March 23d, and this will not occur again till 2008.

Perhaps the most striking phenomena connected with the Moon are its series of phases, which are repeated once every 29.5 days. Being an opaque body shining merely by reflected light, it can be seen only as the light of the Sun illuminates it. In this connection it may be noted that the line of division between the illuminated and unilluminated portions of the disk is called the terminator. It is always a semi-ellipse, and its advance marks the progress of the lunar day. When the Moon is between the Earth and the Sun, its dark side is turned toward the Earth, the illuminated side being, of course, toward the Sun. It is then entirely invisible, and this unseen phase is the real new moon, as announced in the almanac. About two or three days later, a thin crescent of silvery light, with horns turned from the Sun, appears in the evening twilight, just after sunset, and this crescent is commonly called the new moon. Bryant refers to it as:

> That glimmering curve of tender rays
> Just planted in the sky.

Gradually the crescent broadens out, as the Moon moves away from the Sun, until on or about the seventh day—the Moon changing approximately every seven and a half days—it reaches a position designated as its first quarter, and is then a bright semi-circle off in the south at sunset. During the next few days, as the Moon moves eastward, more and more of its illuminated surface is brought into view, until three-quarters of the disk appears lighted up, and it is then said to be gibbous. On or

Paris Observatory

PLATE XXVI. The Moon at Nineteen Days

(Image inverted as in astronomical telescopes)

about the fourteenth day, the Moon is opposite the Sun, and the whole of its round disk appears illuminated. It is then alluded to as full moon (Plate XXV.), rising about sunset and setting about sunrise, and represents the phase of most brilliant illumination. Passing on in its orbit, its phases recur in reverse order, the full phase giving place to the gibbous, and this in turn to the semicircle, or last quarter, which phase it reaches somewhere about the twenty-first day, and is then seen high in the heavens in the early morning hours. Step by step it draws closer to the Sun, thinning down to a crescent shape again, with the horns turned from that luminary, until it is lost once more in the solar glare, only to re-emerge, on or about the twenty-eighth day, as new moon, and begin again its cycle of change.

When the Moon shows a very thin crescent, the dark portion of the lunar globe can be dimly seen standing out against the sky, shining with a faint, soft light, called the ashen light—*la lumière cendrée.* The appearance is popularly known as the "old moon in the new moon's arms" (Plate XXVII.), and is sometimes termed earth-light or earth-shine. In the famous old Scotch ballad of *Sir Patrick Spens*, allusion is thus made to the phenomenon:

> I saw the new moon late yestere'en,
> Wi' the auld moon in her arms.

It is simply the light which the Earth reflects from its surface to the Moon—the reflection of a reflection—and by the weather-wise is looked upon as a sign of fair weather. There is a widespread popular belief, handed down from remote antiquity, that the Moon's changes influence the weather. Unhappily this belief is not restricted to the uneducated classes, but is more or less

prevalent among the intelligent and well-informed. Every one knows that when a line joining the horns or points of the Moon's crescent lies nearly perpendicular to the horizon, so that the crescent cannot hold water, the Moon is popularly called a *wet moon*, and that when it is almost horizontal, so that the crescent can apparently hold water, the Moon is termed a *dry moon*, and is commonly considered a sign of fair weather. And further, that a three-days-old moon clearly seen denotes fine weather, while to see the Moon in the daytime foretells the approach of cool days. Or again, that when a large star or planet is seen near the Moon, or as sailors express it, "a big star is dogging the Moon," it is a certain sign of boisterous weather.

In her account of the burial of poor old Thias Bede by the "White Thorn," George Eliot in *Adam Bede*, Chapter XVIII., refers to one of the more common beliefs, when she makes old Martin say to his son: "It' ud ha' been better luck if they'd ha' buried him i' the forenoon when the rain was fallin'; there's no likelihoods of a drop now, an' the moon lies like a boat there, dost see? That's a sure sign o' fair weather; there's a many as is false, but that's sure." The crescent moon appearing either supine or prone has, however, no more to do with weather changes than has the Panama Canal or the Monroe Doctrine. A little reflection will show that the cusps or horns of the new moon must point from the Sun, and that as the ecliptic is differently inclined to the horizon at various times of the year, the crescent will also occupy a different position with reference to the horizon. There is, it may be noted, a real but ill-defined seven-day period of the weather which is a genuine phenomenon and is probably due to terrestrial causes, having nothing

Plate XXVII. Earth-Shine on the Moon

Plate XXVIII. The Planet Venus, Showing Crescent Phase

whatever to do with the Moon. The facts as regards the Moon and the weather are perhaps fairly represented in the trite jingle:

> The Moon and the weather
> May change together,
> But change of the Moon
> Does not change the weather;
> If we'd no Moon at all—
> And that may seem strange—
> We still would have weather
> That's subject to change.

The young, innocent-looking crescent moon has on more than one occasion been a trouble to novelists. One prominent writer is credited with having described a star as shining between the horns of the crescent moon, as though there were no dark body there to intercept a view of the star, and even Coleridge, in Part Third of his *Rime of the Ancient Mariner*, makes the mariner thus allude to the rising moon:

> The horned Moon with one bright star
> Within the nether tip.

And again, it is said that Marryat, sea-captain though he was, wrote of a waning crescent moon seen in the early evening; and Sir H. Rider Haggard in *King Solomon's Mines*, Chapter IX., hints at a full moon seen in the west soon after sunset, thus: "The sun sank and the world was wreathed in shadows. But not for long, for see in the west there is a glow, then come rays of silver light, and at last the full and glorious moon lights up the plain." Furthermore, Baroness Orczy, in *Petticoat Rule*, Chapter VIII., pictures "a fair crescent moon, chaste and cold," appearing "far away to the east,

others have seen there a lion, a dog, and in particular a hare. In Plate XXXI., reproduced by permission from W. H. Pickering's *The Moon*, are given sketches of the full moon by various persons showing what they fancied they saw with their unaided eye: 1. The Face; 2. The Crab; 3. The Girl Reading; 4. The Donkey; 5. The Lady; 6. An Astronomer's Drawing. The head of the woman will usually be seen on the extreme right or western half of the Moon, with the face, which is bright, turned toward the left or east, across the disk, although at times it is in the lower right-hand corner, with the face looking upwards. The outlines of the forehead, nose, mouth, and chin are formed by the Sea of Showers, or Mare Imbrium, and the Sea of Clouds, or Mare Nubium, and the figure is best seen with the aid of an opera-glass of low power. Perhaps the most interesting of all the faces is that of the "moon-maiden," with long floating hair, looking out from the Heraclides Promontory, the eastern cape of the beautiful Bay of Rainbows, or Sinus Iridum, across the great Sea of Showers. Unfortunately, however, it can only be seen with the aid of the telescope, and only when the Sun is shining properly upon it. Shakespeare, in *The Tempest*, Act II., Scene 2, makes reference to the Man in the Moon, when Caliban and Stephano are conversing with each other, thus:

Caliban: Hast thou not dropped from heaven?
Stephano: Out o' the moon, I do assure thee, I was the man in the moon, when time was.
Caliban: I have seen thee in her, and I do adore thee; my mistress showed me thee, and thy dog and bush.

The Moon is most interesting not at full, but rather at about the time of the first quarter, when the details

of objects on the lunar surface are brought into clear relief by their shadows. In even a large opera-glass or prism binocular, the ill-defined dark markings which to the naked eye, at full moon, seemed to make up the picture of a lugubrious face are changed and show up as the shadows of great mountains. When viewed with a telescope of moderate size, the lunar globe appears as a great, round, silvery ball, marked here and there with extensive dark areas, and pitted all over with crater-like formations. If observed at or near the full, curious systems of bright streaks or luminous rays radiating in every direction from certain well-marked centres will be seen, one of which, the magnificent system which radiates from the great crater-mountain Tycho, near the Moon's south pole, is so conspicuous, that along with the dark-hued plains or "seas" it makes the full moon bear some resemblance to a badly-peeled orange.

Speaking roughly, the various types of formations which diversify the Moon are its large, low-lying, grey plains, its walled plains, and its circular or approximately circular formations, generally known as "craters," its mountain ranges and isolated mountains, its deep narrow clefts and rills, and its curious system of bright rays.

The great grey plains, here and there marked by winding ridges and small crater-like formations, and commonly known as *maria* or "seas," occupy about one-third of the visible lunar surface and are found mainly in the northern hemisphere. They receive the name of maria because the earlier selenographers believed they were really lunar seas, and though they have no right to the title, the designation has been retained to this day. The one that appears to be most perfectly enclosed is the Mare Crisium (the Sea of

Crises), in the north-west quadrant of the Moon. It is about 360 miles in width from east to west and 280 miles in length, and has an area of nearly 70,000 square miles. It may often be distinguished without optical aid, and is sometimes clearly seen by daylight. The other maria, with the exception of the comparatively small Mare Humorum (the Sea of Humours), are only partially bounded, being connected with each other as are the oceans on the Earth.

The most important of the large maria is the vast Mare Procellarum (the Sea of Storms). It extends along the eastern side of the disk and has an area of nearly two million square miles. In the north-east quadrant is the great greyish Mare Imbrium (the Sea of Showers). Besides the Mare Crisium, in the north-west quadrant, toward the centre of the lunar disk is the Mare Vaporum (the Sea of Vapours), while adjoining it are the Mare Tranquillitatis (the Sea of Calm) and the Mare Serenitatis (the Sea of Serenity), the Lacus Somnorum (the Lake of Dreams) lying to the north and west again of the Mare Serenitatis. In the south-west quadrant lie the Mare Fecunditatis (the Sea of Fertility), and the Mare Nectaris (the Sea of Nectar), while in the south-east quadrant, between the Mare Imbrium and the middle of the Moon, lies the Mare Nubium (the Sea of Clouds). Near the north pole is situated the Mare Frigoris (the Sea of Cold), exceedingly elongated laterally. The larger so-called gulfs of the "seas" are the Sinus Roris of the Mare Procellarum and the celebrated Sinus Iridum of the Mare Imbrium.

The most striking features of the Moon are its crater-like formations and walled plains, which have, as a rule, been named after celebrated persons, usually men of

science. By some they are supposed to have been of volcanic origin, and by others to have been formed by explosions of vast accumulations of gas in the interior of the Moon; their real origin, however, is unknown. Some 33,000 have been mapped, and according to W. H. Pickering the total number visible under favourable conditions exceeds 200,000. The walled plains have a diameter of from 45 to 150 miles, and are encircled by an irregular and often interrupted boundary, which in some cases rises to the height of about 12,000 feet above the enclosed plains. The interior is, as a rule, comparatively flat, or diversified by the presence of a few minute craters and irregular mountains. Most of the walled plains lie in the southern hemisphere of the Moon, where quite often several are found close together in a row.

The lunar craters, so-called, have a smaller diameter than the walled plains, and are usually made up of a ringlike wall, enclosing a central plain or "floor," which is often much depressed below the outside level. On the floors of the larger craters, numerous pits or craterlets are found, and not infrequently central peaks rise to the height of the crater-walls. Like the walled plains, the craters are seen in greatest numbers in the southern hemisphere, the surface in the region of the Moon's pole being literally riddled with pits and holes.

The craters vary greatly in size, the largest being nearly one hundred miles in diameter, and the smallest discernible, less than half a mile. The largest known terrestrial volcanic crater, Aso San in Japan, does not exceed seven miles in diameter, while the number of those on the Moon which exceed seven miles can be counted by hundreds. One of the larger lunar craters—the great walled-plain Ptolemæus—located near the

centre of the visible hemisphere, is about 115 miles across, while in one of its peaks it rises to the height of more than 9000 feet above the enclosed plain. Shickard, close to the south-eastern border, is about 134 miles in diameter, and its walls rise in one point to over 10,000 feet, while Clavius, near the southern edge of the Moon, measures no less than 143 miles in its greatest length, and has a depth of two and a half miles. One of the peaks upon its walls rises to a height of 17,000 feet. Clavius is remarkable for the number of small craters associated with it, and is looked upon by many as the most variedly beautiful and impressive of all the lunar formations.

On the eastern boundary of the Mare Procellarum is the dark oval called Grimaldi, one of the largest wall-surrounded plains on the Moon. It extends 148 miles from north to south, and 129 from east to west, and covers an area of about 14,000 square miles. It is the darkest spot on the lunar surface, the radiant Aristarchus—about twenty-eight miles in diameter—being the brightest. One of the most interesting craters is Theophilus, situated on the southern border of the Mare Tranquillitatis. It is a large ringed plain about sixty-four miles across, and from 16,000 to 19,000 feet deep, and has an area of about 3200 square miles. Some of the peaks upon its ramparts rise 18,000 feet above the crater floor. One of the cone-shaped mountains in its centre is 6000 feet high, yet its summit is some 4000 feet lower than the level of the outside plain. It is probably the most perfect and deepest ring-mountain on the Moon. When the Moon is five to seven days old or eighteen to twenty days old, the superb triple group of walled plains formed by Theophilus, Cyrillus, and Catharina

may be clearly distinguished by a prism binocular field-glass.

Near the northern edge of the Moon may be seen a dark oval spot—the great walled plain Plato (Plate XXX.). It is a coneless crater, about sixty miles across, and is easily recognised at full moon. Scattered about on its decidedly convex floor, are some thirty or more small craters. On the western border of the Mare Fecunditatis is Langrenus, a magnificent walled plain, with walls from 8000 to 10,000 feet high. It is about ninety miles in diameter, and its central peak is over 3000 feet in height. The crater Gassendi, in the south-east quadrant, is fifty-eight miles in diameter, and about 8000 feet deep. It comes into view about three or four days before full moon.

The brilliant round crater Tycho, not far from the Moon's south pole, is almost sixty miles in diameter, and its crater wall rises to a height of over 16,000 feet. Its central, cone-shaped mountain is between 5000 and 6000 feet high. Tycho is the most famous of the crater mountains, and forms a brilliant breast-pin for the "Lady in the Moon." It is connected with the most remarkable of ray systems, and has been called by Webb the "metropolitan crater of the moon." Within a few days of full moon, the crater and the bright rays constitute the most striking feature of the whole lunar surface, and can even be seen by the unaided eye. The rays at that time traverse almost one-fourth of the visible lunar disk, radiating from the crater, like spokes from the hub of a wheel. Around its massive and regular ramparts lie a large number of formations, part of which are somewhat irregular structures, and part walled plains. Moreover, in its region may be seen a large number of crater-like depressions and crater cavities.

Perhaps, the grandest of lunar craters is the great ring-plain known as Copernicus (Plate XXIX.). It measures about sixty miles across and is situated toward the eastern edge of the lunar disk, on the tip of the nose of the "Man in the Moon," between the Showery, Stormy, and Cloudy Seas. Like Plato, it is distinguished for its system of bright rays, as well as for its massive and regular ramparts, which are crowned by a number of bright peaks, one of which attains the height of 14,800 feet. Inside the not quite circular walls, near the centre of the crater floor, are four or five cone-shaped mountains, the centre one of which is over 11,000 feet high. The numberless bright streaks surrounding Copernicus rival in splendour the magnificent system which radiates from Tycho, though the latter are by far the most noteworthy. During the last century one little crater known as Linné (Plate XXX.), seen as a white spot in the Mare Serenitatis, has seemed to undergo slight changes, and is even reported by some to have been invisible for a time. Whether the suspected changes have been merely illusions due to variable illumination, or are a reality, has not been definitely decided.

Although the majority of the lunar elevations assume the crateriform aspect, a number of long and lofty ranges of mountains, resembling terrestrial mountains, exist on the Moon. The lunar mountains, it may be noted, are not only relatively but actually higher than those of the Earth. Mt. Everest, the giant of the Himalayas, the loftiest mountain in the world, is only a trifle more than 29,000 feet high, while several peaks of the Leibnitz Mountains on the extreme southern edge of the lunar disk are nearly 30,000 feet, and one peak is even said to be 36,000 feet in height. There are

Yerkes Observatory

PLATE XXIX. The Great Lunar Crater Copernicus

more than forty lunar mountains that are higher than is Mt. McKinley, Alaska, the highest peak in North America, its height being only 20,464 feet. Of the larger mountain ranges, most of which are named after terrestrial mountains, the best known are the Lunar Apennines, the Lunar Alps, the Lunar Caucasus, the Lunar Carpathians, the Lunar Pyrenees, the Leibnitz, and the Doerfel Mountains. They are best viewed when the moon is in its first or last quarter.

The Lunar Apennines (Plate XXX.) named by Galileo after the Apennines of Italy, are the greatest and most impressive of the larger mountain ranges. They are upwards of four hundred miles in length, and while many of the peaks are from 12,000 to 20,000 feet high, one in particular attains to the height of 22,000 feet. They run in a north-west and south-east direction, along the border of the Mare Imbrium, and at first quarter form a magnificent spectacle. At the time of full moon, the Apennine range can be seen quite well with the unaided eye, and it makes the nose of the "Man in the Moon." The Lunar Caucasus—separated from the northern end of the Lunar Apennines by a broad path connecting the Mare Serenitatis with the Mare Imbrium—are a mass of highlands and peaks, trending to the west, the highest peak being about 18,300 feet high. The Lunar Alps, on the north-west border of the Mare Imbrium, attain a height of 11,900 feet, and at their eastern end rises the great walled plain, Plato. They are notable for the wonderful Alpine Valley, a chasm which runs through the range in a straight line for upwards of eighty miles. The Valley is about two miles wide at its narrowest point, and about six at its widest, and is an easy object in a two-inch instrument. Among the other mountain

ranges may be mentioned the Lunar Carpathians, 6400 feet in height, to the west of the Mare Procellarum, and close to the great crater Copernicus, the Lunar Pyrenees, 11,900 feet high, on the western edge of the Mare Nectaris, and the Altai Mountains, 13,300 feet in height and 280 miles in length, in the south-west quadrant. At the southern edge of the Moon, are the Leibnitz and Doerfel Mountains, which, so far as known, embrace the loftiest peaks on the visible lunar surface.

In addition to the craters, mountains, and grey plains, there are on the lunar surface other interesting features known as rays and rills. The rills are fissures or rents, from ten to three hundred miles or more in length, about a quarter of a mile in depth, and from less than half a mile to more than two miles in width. They extend in approximately straight lines, frequently traversing walled plains and craters, without any apparent interruption. Among the most conspicuous of these strange chasms are the Serpentine Valley of Herodotus, the well-known Ariadæus and Hyginus clefts, and the deep sharp cleft crossing the floor of Petavius. They are believed to be simply open cracks in the lunar surface, caused by the surface splitting as it cooled down and became too small for its interior.

The rays are long light-coloured streaks, which radiate from several of the principal craters in all directions, and are not well seen except at or near full moon. They extend in some cases to a distance of some hundreds of miles, passing across valley and mountain, and at full moon, rendering some of even the larger craters, such as the great crater-plains Clavius and Maginus, almost unidentifiable. They appear to be neither elevated nor depressed with reference to the general lunar sur-

Paris Observatory

PLATE XXX. The Lunar Apennines, Alps, and Caucasus

(Image inverted as in astronomical telescopes)

face, and are ordinarily from five to ten miles in width. The ray system connected with Tycho is by far the most noteworthy, although those in connection with Copernicus and Kepler are very striking. As to their origin and nature little is known. By some it is supposed that they were originally great cracks caused by internal pressure, which have been filled, either with lighter coloured material forced up from below, or with a whitish powder emitted by the craters from which the rays issue.

From earliest times, in all quarters of the world, the cold chaste Moon has been an easy and favourite subject for myth making. There have been seen in it by every age and race, a "Man in the Moon," a "Woman in the Moon," a "Hare in the Moon," and so on, while various and innumerable have been the legends regarding them. According to Teutonic legend the Man in the Moon was an old wood-cutter, who while travelling on Sunday with a bundle of sticks on his back was met by a fairy who stopped him and remonstrated with him for working on the Sabbath. He laughed and replied, "Sunday on earth, or Monday in heaven, it's all one to me!" "Then carry your bundle for ever!" she answered; "and as you regard not Sunday on Earth, you shall stand for eternity in the Moon!" Thereupon, as the fairy vanished, the wood-cutter was caught up with his bundle into the Moon, where he still stands.

In Gyffyn Church, near Conway in Wales, there is a pictorial representation of the Sabbath-breaker, in which the moon is depicted as a big round disk in which is the man with his bundle of sticks. According to a Dutch myth, the Man in the Moon was transported there for stealing cabbages on Christmas Eve. An Indian legend regarding the dark spots on the Moon is

told in Longfellow's *Song of Hiawatha*, Chapter III., where little Hiawatha

Saw the moon rise from the water,
Rippling, rounding from the water,
Saw the flecks and shadows on it,
Whispered, "What is that, Nokomis?"
And the good Nokomis answered,
"Once a warrior, very angry,
Seized his grandmother, and threw her
Up into the sky at midnight;
Right against the moon he threw her;
'Tis her body that you see there."

In Greek legend there is a pretty little story of Selene (the Moon), and Endymion, a beautiful youth renowned for his perpetual sleep. As the story runs, while the latter slept on Latmus, a mountain in Caria, whither he had come from Elis, Selene, charmed by his surprising beauty, came down to him from the sky, and kissed him. Shakespeare in *The Merchant of Venice*, Act V., Scene I., thus alludes to this episode:

Peace, ho! the moon sleeps with Endymion,
And would not be awaked!

In the British Museum there is a beautiful statue of a sleeping Endymion.

There is a Buddhist legend, according to which the god Indra, while walking through the woods disguised as a Brahman, met a monkey, a fox, and a hare travelling together, and pretending to be starving, asked them for something to eat. The three at once started off in search for food, the monkey bringing back a bunch of mangoes, and the fox a pot of milk he had stolen, the hare alone returning from the quest unsuccessful. Not wishing to

From W. H. Pickering's *The Moon*

PLATE XXXI. Lunar Fancies

appear lacking in hospitality, the hare said to the Brahman, "If you are very, very hungry, light a fire and roast and eat me." "All right," said the Brahman, "I'll kindle a fire at the foot of this rock and you jump off into it." Immediately the fire was built, the hare leapt in, but was snatched from the flames by the god, and in reward for his heroic self-sacrifice was placed in the Moon, where he may be seen to this day.

Among some Indian tribes, a legend exists that the dark spots on the Moon represent a little child carrying a basket. The myth relates that the child cried out in the night for water, but the mother, tired and sleepy, heeded not its cry. Whereupon, the Moon, who felt sorry for the child, appeared with a pot of water from heaven, and said, "Here, little one, is water to drink." The child eagerly drank the water and was then carried by the Moon up into the sky, taking with her the little basket she held in her hand. In Chinese legend, the Man in the Moon is known as Yuelao, and is supposed to govern marriages. Such young men and maidens as he desires to make husband and wife are tied together with an invisible silken cord, which is not severed until death. Verily, as suggested by Harley in his *Moon-lore*, Yuelao must be the man in the "honey-moon."

One of the chapels adjoining the principal building of the Temple of the Sun at Cuzco, Peru, was consecrated to the Moon, who was acknowledged as the sister-wife of the Sun, and was the deity held next in reverence, as the mother of the Incas. Her effigy was delineated on a vast plate of silver, that nearly covered one side of the apartment. In Babylonian mythology, the Moon took precedence of the Sun, and was the first among divinities. In Greece the Moon became Selene, and with the Romans was identified

with the goddess Diana. Thus Ben Jonson in his hymn to Cynthia wrote:

> Queen and huntress chaste and fair,
> Seated in thy silver chair,
> Now the Sun is laid to sleep,
> State in wonted manner keep.

One of the most common superstitions concerning the Moon is the expectation of good luck if the new moon be first seen over the right shoulder. It is narrated by Aubrey that the Scotchwomen in his time made a curtsey to the new moon, and that it was customary in England for rustic belles, as soon as they saw the first new moon after midsummer, to go to a gate or stile, turn their back to it, or sit astride, and say:

> All hail, new moon, all hail to thee!
> I prithee, good moon, reveal to me
> This night who shall my true love be;
> Who is he, and what he wears,
> And what he does all months and years.

A dream is expected to follow, giving the information so greatly desired.

Halliwell mentions a prayer, customary with some persons, which runs as follows:

> I see the moon and the moon sees me,
> God bless the moon, and God bless me.

CHAPTER VII

THE ECLIPSES

Virgil, in his second *Georgic*, in his petition to the Muses, writes:

> "Give me the ways of wand'ring stars to know,
> The depths of heav'n above, and earth below,
> Teach me the various labours of the Moon,
> And whence proceed Eclipses of the Sun."

THE eclipses of the Sun and the Moon, otherwise known as the solar and the lunar eclipses, are among the most impressive and magnificent of all the phenomena of the heavens. They are produced only when the new moon or the full moon is at or very near one of the nodes—that is one of the two points where the plane of the lunar orbit intersects the plane of the ecliptic, or of the Earth's orbit. Were the orbits of the Earth and the Moon exactly in the same plane or level, an eclipse would happen every time the Moon was new or full, or about twenty-five times a year. As a matter of fact, however, the plane of the Moon's orbit is inclined to the plane of the Earth's orbit at an angle of about 5°, which in popular language is an elevation of nearly nine in a hundred; and besides, the Moon's nodes are not stationary, but have a daily retrograde motion of 3′ 10.64″, owing to the attraction of the Sun on the Earth and Moon. The motion of the nodes backward or west-

ward on the ecliptic resembles that of the equinoxes, only it is much more rapid, the entire circuit of the celestial sphere being completed in a little less than nineteen years. As a result of this backward motion of the Moon's nodes, the eclipses occur, on an average, about nineteen days earlier every year than they did the year previous.

The average time required by the Moon to journey in its orbit, from one node back to that node again, is 27 days, 5 hours, 5 minutes, and 35.81 seconds, which constitutes what has been called the nodical or draconitic month. Since 242 draconitic months very nearly equal 223 synodic months, being about eighteen years, eleven and a third days, and both are nearly equal to nineteen eclipse years—an eclipse year being the time occupied by the Sun in passing from a node to the same node again—it follows that after the lapse of that interval Sun, Moon, and nodes will be in very nearly the same relative position again. If, then, an eclipse should occur at a given date, a very similar eclipse will occur again at the end of eighteen years, eleven days, and eight hours, but not on the same part of the Earth's surface. This recurrence of solar and lunar eclipses after intervals of about 18.03 years is known as the *Saros*, and tradition points to the Chaldeans as its discoverers, more than twenty-five hundred years ago. The usual number of eclipses in this space of time is about seventy-one, of which twenty-nine are of the Moon and forty-two of the Sun. The greatest possible number of eclipses in any one year is *seven*, five solar and two lunar, or four solar and three lunar, and the least is *two*, in which case both will be solar. The usual number of eclipses, however, is four, two of which are solar and two lunar. There will be seven eclipses

(a somewhat rare occurrence) in 1917, four of which will be of the Sun and three of the Moon. In 1935, also, there will be seven eclipses, five of the Sun and two of the Moon.

Eclipses of the Sun—that is, eclipses caused by the Moon's shadow falling on the Earth—take place at the time of new moon, and always come on from the west or right-hand side, and pass over eastward; while eclipses of the Moon—that is, eclipses caused by the immersion of the Moon in the shadow of the Earth—occur at the time of full moon, and come on from the east and pass over westward. The solar eclipse limits, or the distances on each side of the node within which a solar eclipse may happen, vary from $15\frac{1}{5}°$ to $18\frac{1}{2}°$ in either direction; and the lunar eclipse limits, or the distances on each side of the node within which a lunar eclipse may occur, vary from $9\frac{1}{2}°$ to $12\frac{1}{4}°$ in either direction. The proportion of the solar eclipses to the lunar eclipses is about as three to two. There are, however, more visible eclipses of the Moon at any given place on the Earth's surface than of the Sun, because a lunar eclipse is visible over the whole unillumined hemisphere of the earth, while the region in which a total solar eclipse is visible never exceeds 165 miles in breadth, although for about 2000 miles on either side of the track of totality the Sun may be seen partially eclipsed. Not infrequently a lunar eclipse takes place about fifteen days before or after a solar one.

Lunar eclipses are of two kinds, total and partial; total when the Moon is completely immersed in the Earth's shadow, and the whole lunar disk is darkened (Plate XXXII.), and partial when a portion of the lunar disk remains outside of the true shadow, so that only a part of the disk is darkened. At the average distance

of the Moon from the Earth, the diameter of the shadow is a little over 5700 miles. When the Moon passes through the centre of the Earth's shadow, the eclipse may continue total for about two hours, the interval between the first and the last contact being about two hours additional. On account of the refraction of the solar rays in traversing the Earth's atmosphere, the Moon is, usually, not totally invisible, and yet in the lunar eclipse of 1884 it was, for a time, absolutely invisible to the naked eye. Ordinarily the eclipsed Moon shines with a pale coppery light, owing, it is believed, to the fact that the blue and green rays are absorbed by the atmosphere. Sometimes, however, the lunar surface has a greyish-blue tinge, as in the phenomenon known as the "black eclipse." There are two or three eclipses of the Moon every year, of which one at least is nearly always total. Every inhabitant of the Earth, therefore, may be in a position to see, on an average, half of all the total lunar eclipses that happen during his lifetime; not so, however, with the total solar eclipses, which are relatively rare phenomena. It is found that a total eclipse of the Sun happens at any given place on the Earth's surface only once in about every three hundred years. Though by no means so important as a total solar eclipse, a total lunar eclipse is yet one of the most interesting and beautiful sights in the sky.

The earliest lunar eclipse of which there is any authentic record is that mentioned by Ptolemy as having been observed at Babylon on March 19, 721 B.C. In his *Life of Nicias*, Plutarch relates that when the Athenian general, then in feeble health, prepared in 413 B.C. to return to Greece, after an unsuccessful siege of Syracuse in Sicily, a total eclipse of the Moon

Yerkes Observatory

PLATE XXXII. Total Eclipse of the Moon, Feb. 8, 1906

U. S. Naval Observatory, Washington

PLATE XXXIII. Morehouse's Comet, Nov. 13, 1908

happened. Fearing the malign influence of the phenomenon, Nicias unfortunately delayed his departure, and lost the chance of retreat. He was defeated in a decisive battle by the Syracusans, and both he and Demosthenes, who had been sent with reinforcements from Athens, were captured and put to death. Thus the superstition of Nicias cost him his life, and led to the destruction of his whole army, which marked the commencement of the decadence of Athens. On September 15, in the year 5 B.C., a total lunar eclipse took place, which is supposed to be the one recorded by Josephus as having occurred a little before the death of Herod. It is of more than ordinary importance as serving to determine the date of the birth of Christ.

The total lunar eclipse which happened soon after sunset on March 1, 1504, is celebrated as having most excellently served the purposes of Christopher Columbus in the island of Jamaica, when the venerable admiral and his people were in absolute distress for food. The contumacious natives had refused to longer supply him with provisions, in the hope either of starving him or of driving him from the island. Being aware that a total eclipse of the Moon would shortly occur, he announced to them, on the day of the eclipse, that the great Deity of which he and his followers were worshippers, was incensed against those who had refused to furnish his faithful worshippers with provisions, and intended to chastise them with famine and pestilence. As a sign of the anger of heaven, and in testimony of the fearful punishment which awaited them, he told the natives they would that very night behold the Moon change its colour and gradually lose its light. When the phenomenon took place as predicted, the savages were so terrified that they came in a body and implored him

to intercede with his God to withhold the threatened calamities, assuring him that they would henceforth bring him supplies as much as he needed. Columbus shut himself up in his cabin, as if to commune with the Deity, and when the eclipse was about to diminish, he came forth and informed the natives that his God had deigned to pardon them, on condition of their fulfilling their promises, and in token of which he would withdraw the darkness from the face of the Moon. From that time forward there was no failure in the regular supply of provisions to the Spaniards. The great navigator when he perpetrated this "pious fraud" was about sixty-eight years of age.

One of the best examples of a dark eclipse is that observed at Stockholm on May 18, 1761. According to Wargentin, the lunar disk on that occasion disappeared so completely that it could not be discovered even with a telescope.

As instancing the superstition connected with eclipses still existing among ignorant peoples, it is said that during the lunar eclipse of February 27, 1877, the natives of Laos, Indo-China, amidst terrific yells, fired shots at the eclipsed Moon, in order to frighten off the black dragon whom they imagined was devouring it.

Solar eclipses are of three kinds—total, partial, and annular. A total solar eclipse (Plate XXIII.) takes place when the Moon is exactly in line with the Earth and Sun, at the time of its least distance from the Earth, and its disk just covers that of the Sun. When the Moon is at its greatest distance from the Earth, as it passes centrally over the Sun, it does not entirely cover the Sun, but leaves an uneclipsed ring or "annulus" around it, and thus produces what is known as an annular or "ring-formed" eclipse. A partial eclipse

occurs when the Moon is not exactly in line with the Earth and Sun, and only covers a part of the Sun's disk.

In a total solar eclipse, than which no phenomenon of nature is more impressive, the time which elapses from the moment when the edge of the Moon first touches the western edge of the Sun, until the eclipse becomes total, is about one hour. Under the most favourable conditions possible, a total solar eclipse may continue total, at any given point, for not more than seven minutes and fifty-eight seconds, while the longest possible duration of an annular eclipse, at any selected point, is twelve minutes and twenty-four seconds. Ordinarily the time that the Moon covers the whole face of the Sun is from two to four minutes. About an hour after the total or annular phase, the Moon's disk, which has been making its way steadily across the face of the Sun, finally leaves the solar disk, and the eclipse of the great luminary is over.

Just before the eclipse becomes total, it may be noticed that, when viewed through the telescope, the gradually diminishing crescent of Sun, instead of vanishing all at once, seems to resolve itself into a series of brilliant dots called "Baily's Beads," from their resemblance to a string of glittering beads. No sooner are these so-called beads formed, however, than one after another they rapidly disappear. They are supposed to be bits of sunlight shooting up between such of the lunar mountain peaks, as happen at the time to line the advancing edge of the Moon, and were first systematically described by the English astronomer Francis Baily in 1836. About five minutes before totality, strange, ill-defined, wavy streaks of light, called "shadow bands," may be seen chasing each other across the landscape. With the disappearance of the solar

globe there suddenly spring into view, skirting the black rim of the Moon, those important accompaniments of the Sun, known as the Solar Corona, the Chromosphere, and the Solar Prominences, which have been treated of at length in Chapter III. During the total obscuration of the Sun, the sky puts on a dark, lurid appearance, and a few of the brighter stars and planets may be seen. As at nightfall, birds often cease their songs and fly anxiously to their nests, chickens go to roost, flowers close up, the temperature declines, and dew frequently falls. Suddenly, the brilliant disk of the sun springs into view again at the other side, and the landscape glows with the returning light, while the corona and prominences, the most interesting and most striking sights of the eclipse, fade away.

In olden times, eclipses were, and among unenlightened people still are, looked upon with feelings of indescribable terror, as indications of the anger of heaven, or as presages of impending calamities. The eclipses of the Sun have been regarded with more superstitious fear and awe than have those of the Moon, while both have played a not unimportant part in the world's history. On more than one occasion has the great terror inspired by an unexpected eclipse halted armies on their march, called off impending battles, and rendered combatants eager to come to terms of peace. Herodotus records that a total solar eclipse stopped a battle in the war between the Medes and Lydians, and so disturbed the contending parties that they retired each to their own country. This eclipse, which is said to have been predicted by the Ionic philosopher Thales of Miletus, and was therefore known as the "Eclipse of Thales," seems to have occurred on May 28, 585 B.C. Xenophon relates in his *Anabasis* the tradition that

when the Persian king, Cyrus, besiged the city of Larissa (an ancient city on the eastern bank of the Tigris), but could not capture it, a total eclipse of the Sun occurred (557 B.C.), which created so great a consternation among the inhabitants that they fled, and permitted the city to be taken. In the year 1030, an eclipse, generally known as the "Eclipse of Stiklestad," is said to have taken place during the naval battle at Stiklestad, near Trondhjem, in which the gallant Saint Olaf, King of Norway, was defeated and slain by the Danes. In his *Saga of King Olaf*, Chapter XIX, Longfellow has it that

> there in the mist overhead
> The Sun hung red
> As a drop of blood.

There is an Indian tradition that a great war between the Mohawks and the Senecas, was averted by the timely interposition of heaven, through the total eclipse of the Sun on June 28, 1451. It is related that during the total eclipse of July 29, 1878, many of the Indians at Fort Sill, in what is now "the boomer State" Oklahoma, became greatly frightened. Some threw themselves upon their knees and invoked divine blessing, others flung themselves prostrate on the ground face downwards, while not a few cried and yelled in frantic excitement and terror. At last an old Indian stepped from the door of his lodge, mumbled a few unintelligible words, and then fired a shot at the darkened Sun. As the totality ended about that time, the sun once more peeped forth, greatly to the relief of the terrified Indians, who firmly believed that the old brave's timely shot drove away the unholy shadow and saved the sun from extinction.

Among the most notable eclipses of recent years are those of May 28, 1900, and of August 30, 1905. The track of totality of the former stretched from the western coast of Mexico, across the southern States, over the Atlantic, and then through Portugal and Spain into Africa. Its total phase lasted only for about a minute and a half. The track of the eclipse of August 30, 1905, stretched from Winnipeg across Labrador, and over the Atlantic, through Spain and across north Africa into Arabia. The next really favourable eclipse, that of August 21, 1914, will be a return, after one saros, of that of August 9, 1896. Its track of totality will stretch from Greenland through Norway and Sweden, and across Russia. A total solar eclipse is predicted for September 10, 1923. It will be a repetition of that of August 30, 1905. The longest total eclipse of the Sun on record will take place on June 20, 1955. It will be visible in the island of Luzon, and will last nearly eight minutes.

According to the *Nautical Almanac*, the following eclipses will happen during the next six years: In the year 1914, there will be four eclipses, two of the Sun, and two of the Moon. The eclipse of February 24th will be an annular eclipse of the Sun, and will be invisible at Washington; that of March 11th will be a partial eclipse of the Moon, and will be visible at Washington (mag. 0.916). The eclipse of August 20–21 will be a total eclipse of the Sun, Washington being just within the eclipse limits. The eclipse of September 3–4 will be a partial eclipse of the Moon, invisible at Washington, but visible in western North America, the Pacific Ocean, Asia, and Australia (mag. 0.864).

In the year 1915, there will be two eclipses, both of the Sun, invisible at Washington. Both eclipses will be

annular, and will occur, one on February 13th, and the other on August 10th.

In the year 1916, there will be five eclipses, three of the Sun and two of the Moon. The eclipse of January 19th will be a partial eclipse of the Moon, visible in extreme western Europe, the north Atlantic Ocean, North and South America, the Pacific Ocean, and north-east Asia (mag. 0.137). The eclipse of February 3rd will be a total eclipse of the Sun, visible at Washington as a partial eclipse. The eclipse of July 14th will be a partial eclipse of the Moon, visible in Africa, south-western Europe, the Atlantic Ocean, North and South America, and the Pacific Ocean (mag. 0.800). The eclipse of July 29th will be an annular eclipse of the Sun, invisible at Washington, and the eclipse of December 24th will be a partial eclipse of the Sun, also invisible at Washington.

In the year 1917, there will be seven eclipses, four of the Sun and three of the Moon, and in the year 1918, there will be three eclipses, two of the Sun and one of the Moon.

In the year 1919, there will be three eclipses, two of the Sun and one of the Moon. The eclipse of May 29th will be a total eclipse of the Sun, invisible in North America, but visible in South America and Africa. The eclipse of November 7th will be a partial eclipse of the Moon, visible in North America, except in the extreme western part. The eclipse of November 22d will be an annular eclipse of the Sun, visible as annular in Texas, and as a partial eclipse in the United States generally, except in the north-western part.

CHAPTER VIII

MARS AND THE PLANETOIDS

LIKE Mercury and Venus, the planet Mars (Plate XXXIV.), the nearest planet to the Earth on the farther side, has been known from prehistoric times. During the last thirty-five years, however, it has been the arena, so to speak, of more speculation and controversy than any other member of the solar system. It is a ruddy little planet about 4230 miles in diameter, revolving around the Sun at an average distance of 141,500,000 miles in 686.9 mean solar days, which constitutes a Martian year. In consequence of the eccentricity of its orbit (0.093), which is greater than that of any other planet except Mercury, its distance from the Sun varies as much as 26,000,000 miles. At its nearest approach to that luminary, the planet is 128,000,000 miles distant from it, and 154,000,000 miles when farthest away. Its motion varies in different portions of its orbit, but the average velocity is fifteen miles a second, and it travels over about four-tenths of a degree in the heavens in a day. It receives on the average less than half as much solar light and heat as does the Earth, though when the planet is nearest the Sun, it receives forty per cent. more heat and light than when at its greatest distance from it.

By reason of its proximity to the Earth, Mars comes

Yerkes Observatory

PLATE XXXIV. The Planet Mars, Region of Syrtis Major

(Showing change due to rotation)

into opposition every 780 days. This constitutes its synodic period, which is by far the longest in the planetary system. At the average opposition the planet approaches the Earth to within 48,600,000 miles. If an opposition occurs near the planet's perihelion, the distance is reduced to 35,000,000 miles, but if near aphelion, it is increased to 61,000,000 miles. At the time of conjunction the planet's distance from the Earth sometimes amounts to as much as 249,000,000 miles. When Mars is at its minimum distance from the Earth, it is nearer than any other object in the night-sky, with the exception of the Moon, and at times Venus and Eros, and perhaps an occasional comet. It is then in a most favourable position for telescopic observation, and is more than fifty times as bright as at superior conjunction. At such times the red-faced planet has three times the brightness of Sirius, while when most remote it is hardly as bright as Polaris. It then shows in the telescope, with a power of seventy-five, a disk about as large as that of the Moon to the unaided eye. When in or near opposition its form is sensibly globular, but in other portions of its orbit it shows a slight phase, which is, however, never more than a dull gibbosity.

The most favourable and brilliant oppositions always occur late in August or in the early part of September, and are repeated at alternate intervals of fifteen and seventeen years. The least favourable oppositions happen in February and March. The last brilliant perihelion opposition took place September 29, 1909, and the next exceptionally brilliant one will occur during the last week of August, 1924. And yet at some of the intervening oppositions (which occur nearly two years and two months apart), most interesting views

of the planet's surface may be obtained. The planet will be in opposition in January, 1914, and may be seen in the evening from then on until the following autumn. Early in 1916 it will rise at sunset and will shine in the evening throughout the summer and fall. The next two oppositions will take place early in 1918 and 1920, and will be followed by a splendid one in the early summer of 1922.

Mars rotates on its axis in 24 hours, 37 minutes, and 22.65 seconds, which makes its day a trifle longer than a terrestrial one. The inclination of its axis to the plane of its orbit is about twenty-four degrees and fifty minutes, or about one degree and twenty-three minutes more than that of the Earth's axis. The Martian seasons, therefore, correspond very closely to those of the Earth, but owing to the greater length of Mars's year, they are almost twice as long, summer in the northern hemisphere lasting 381 days and winter 306 days. In the southern hemisphere the winter is longer than the summer, the former being longer and colder and the latter shorter and hotter than in the northern hemisphere.

Mars, like the Earth, is slightly flattened at the poles (about $\frac{1}{190}$) and bulged at the equator. Its mass is not much more than one-tenth (0.105) of the Earth's mass, and its surface is a little over one-fourth (0.285) as extensive as that of the Earth. The mean density of the planet is a trifle more than seven-tenths (0.71) that of the Earth, and its force of gravity about four-tenths (0.38).

The atmosphere surrounding and enveloping Mars is probably far less dense than that of the Earth. On theoretical considerations it should hardly exceed one-seventh the density of the Earth's atmosphere. It was

estimated by Maunder, as far back as 1882, to be as thin and rarefied as is the atmosphere on the tops of the highest terrestrial mountains. Although spectroscopic evidence in regard thereto has been conflicting, the belief exists that there is some water-vapour in the Martian atmosphere, and most of the time a few thin, semi-transparent clouds. A Martian spectrum taken as recently as 1909, by Campbell, from the summit of Mount Whitney (14,898 ft.), it may be mentioned, showed an absence of water-vapour, however, as it was destitute of certain bands called water-vapour bands.

Viewed through a telescope, the Martian surface presents certain light and dark markings, the former appearing as bright reddish-yellow areas and the latter as areas of a dark greenish-grey or bluish-grey shade. By early telescopic observers the reddish-yellow areas were supposed to be continents and the darker areas seas and oceans, and names were assigned to the more prominent features. Now, however, it is believed that there are no large bodies of water on Mars. The reddish areas, which cover nearly five-eighths of the planet's surface, are to-day looked upon as desert land, while the blue-green areas, which cover about three-eighths of the surface, are supposed to be merely tracts of vegetation. The surface of the planet is more or less irregular and rough, showing hills, plateaus, and even mountain ranges. The bright projections on the terminator, first noticed in 1890, are referred by Campbell to snow-covered mountains, and by Lowell to sunlight striking on a great dust-cloud. Around the poles are plainly to be seen brilliant rounded spots, the famous so-called polar caps. They were discovered in 1719 by the French astonomer Maraldi, and are believed to be composed of snow and ice. They vary in extent

with the Martian seasons, sometimes entirely vanishing at midsummer, reappearing rather suddenly in the autumn, and extending down twenty-five to thirty-five degrees from the pole during the winter. As the polar caps diminish, narrow dark rims are seen around them, which are believed to be the result of the melting of the polar snows. One suggestion—a not very plausible one—for explaining the polar caps is that they may not be due to fallen snow, but to carbonic acid gas (carbon dioxide) which is known to condense into a snowlike substance at a temperature of $-109°$ F., and to dissolve at a correspondingly low temperature.

Carbon dioxide, like water-vapour, it may be noted, has the property of strongly absorbing solar light and heat, and in the Earth's atmosphere it is one of the substances which tends to produce a high mean temperature. Hence the suggestion has been made that a slight excess of carbon dioxide in Mars's atmosphere might so alter the temperature gradients as to keep the average temperature at the planet's surface at a point compatible with plant and animal life and growth. Of this, however, nothing is with certainty known. All that can be definitely stated in regard to the average temperature at the surface of Mars is that it is much lower than that of the Earth—probably below the freezing point of water—and that the temperature is more subject to extremes in variation. The theoretical temperature according to Stefan's law is found to be thirty-three degrees below zero. And yet, it is quite likely that there are mitigating circumstances, at present unknown, that soften down the rigours of Mars's seasons, and make them milder than now seems possible.

After a close study of the planet made during the favourable opposition of 1877, the eminent Italian

astronomer Giovanni Schiaparelli, at the Milan Observatory, found its surface crossed and recrossed by many narrow, dark-greenish streaks, which he called *canali*—a word which is properly translated "channels," but was unfortunately interpreted to mean canals in the artificial sense. These streaks, which were supposed to begin and end in the dark areas, varied in width from about fifteen to sixty miles, and in length from a few hundred miles to one-third the entire circumference of the planet. At the next opposition, and again at the opposition of 1881, the assiduous Schiaparelli reobserved most of these canali, and discovered many more, some of which were seen double, a phenomenon called "gemination." For many years his observations were received with a considerable amount of doubt and hesitation, but in 1886, Perrotin, at Nice, noted a few of the larger canali, and confirmed some of the markings. At the opposition of 1892, Pickering at Arequipa detected many of the canali and observed at their junctions numerous small round dark spots, which were first called "lakes," but are now known as "oases."

That the canali are actual features of the planet's surface—whatever their meaning may be—was definitely established in 1905, from a photograph of Mars secured by Lampland at Lowell Observatory. These canali are by far the most mysterious of all the Mars phenomena, and their appearance is synchronous with the gradual disappearance of the polar snows. They cannot be seen, however, except in large instruments, and under perfect atmospheric conditions. Moreover, what are really seen in the telescope are not the narrow water channels themselves, which are too small to be seen at such a distance, but the fringe of plant growth

along the banks. They stand out boldly in Plate XXXV., a map of Mars designed by that most eminent observer of the planet, Percival Lowell. When Schiaparelli first discovered the canali, he believed them to be natural waterways, through which the water from the annual melting of the polar snow-fields flows toward the equator, but in his later years he averred their artificiality. Along with Lowell, Flammarion, and other zealous observers, he confidently asserted that these markings are the features of a vast irrigation system, that they are in reality "canals," and that Mars is inhabited by a race of superior beings. Without doing injustice to any one, it may be safely said that statements made as to the existence of beings on the ruddy little world are somewhat speculative. Whether conscious, intelligent life flourishes there is not positively known, and may never be known. As to the canali themselves, the belief most generally held by astronomers is that they are not true canals, but are due to cracks or clefts in the Martian surface, such as might be made by nature. Along the sides of the cracks or clefts are ribbons of vegetation, nourished by the water-vapour escaping from them, and these are the dark-greenish streaks, "vegetal canals," so to speak, which are visible in the telescope.

In addition to the canali observed by Schiaparelli, Lowell and his assistants at the famous Lowell Observatory at Flagstaff (6800 ft.), Arizona, have found many so-called canals, which differ radically from the markings observed by the Italian astronomer. Lowell speaks of these streaks as being extremely narrow, and of uniform width from beginning to end, and as forming a complete network over the Martian surface. Nearly seven hundred of the more noticeable of these mysterious linelike markings have been catalogued, about

Lowell Observatory

PLATE XXXV. A Map of the Planet Mars

(The image is inverted as in astronomical telescopes. The Syrtis Major or "Hour-glass Sea," usually the most conspicuous object on the red planet, a white "polar cap," several "oases," and a large number of the famous so-called "canals," some of which are doubled, are well represented here)

sixty of which are described as "doubled canals." The duplicated canals, it is said, appear to their best advantage in the late Martian summer and fall of the northern hemisphere. The small so-called canals are estimated by Lowell to have an actual width of two or three miles, and the larger ones a width of from fifteen to twenty miles. While many observers have seen and mapped numerous lines and markings, comparatively few have been able to see the pencil-like network of lines as mapped at the Lowell Observatory. The elegant drawings of Keeler and Barnard made at the Lick on Mount Hamilton show soft, irregular shadings and hazy, ill-defined streaks, quite unlike the distinct lines and markings shown in the rare and detailed drawings of Lowell.

After the polar caps, the most conspicuous object on the Martian surface is the Syrtis Major or Hour-glass Sea, which is seen fully presented in Plate XXXV. It was observed by the famous Dutch astronomer Huyghens in 1659, and was the first marking detected on Mars. In shape it is not unlike the North American continent.

Mars has two extremely minute satellites, or moons, revolving around it, at rather close quarters, and with great rapidity. They were first seen by the late Asaph Hall at Washington in August, 1877, with the great telescope of the Naval Observatory, the largest telescope then in existence. They were named Deimos and Phobos, these being the names of the steeds said by Homer to have drawn the chariot of Mars, the war-god of Olympus. They are the tiniest bodies in the solar system, with the exception possibly of some of the fainter planetoids. Neither satellite is visible except when the planet is in opposition and generally a tele-

scope of from twelve to eighteen inches diameter is required to see them. The diameter of Phobos, the inner satellite, is estimated at thirty-six miles, and that of Deimos at ten miles. Deimos makes a complete circuit around Mars, at a distance of 12,500 miles from the surface of the planet, in thirty hours and eighteen minutes, while Phobos completes a revolution in seven hours and thirty-nine minutes, at a distance of only 3700 miles from the planet's surface. Deimos rises in the east and takes five hours and forty-one minutes more time to revolve around Mars than the latter takes to rotate on its axis. Its mean period from meridian around to meridian again is 131 hours and 15 minutes, during which it goes through its phases four times.

The period or month of Phobos, the brighter and the nearer satellite to the planet, is the shortest known, and is less than one-half the length of a Martian day. The swift revolution of the satellite, combined with the motion of Mars on its axis, would make it appear to the inhabitants of the planet, if there are any, to rise in the west and set in the east. It crosses the heavens in eleven hours and seven minutes, and during that time goes through all its phases, from new to full, one and a half times.

In mythology Mars was one of the principal Roman divinities, and at an early period was identified with Ares, the Greek god of war. Next to Jupiter he enjoyed the highest honours at Rome, where he was worshipped as the god of war and of carnage, and where numerous temples were dedicated to him. His priests, the twelve Salii, danced in full armour, and the place dedicated to gymnastic and warlike exercises was called after his name, *Campus Martius*, the "Plain of Mars." He

was one of the three tutelary divinities of Rome, and is frequently designated "Father Mars." He was the reputed son of Jupiter and Juno and is generally represented on antique monuments and medals as a robust man armed with a helmet, pike, and shield. Sometimes, dressed in a brilliant suit of armour, he is mounted on a war-chariot, which is guided by Bellona or Enyo, the goddess of war, and drawn by two steeds, named Phobos and Deimos, or Alarm and Dread.

THE PLANETOIDS

In the vast space between the orbits of Mars and Jupiter lie a host of tiny celestial bodies, variously known as planetoids, asteroids, or minor planets. They encircle the Sun at an average mean distance of about 246,000,000 miles from that luminary, and according to Bode's Law occupy a place in the sky that should be occupied by a single large planet. They were at one time supposed to have been the result of a planetary explosion, but the theory now held is that in the original nebula, the shapeless fragments of matter forming the planetoids were prevented from condensing into a planet by Jupiter's disturbing influence.

Bode's Law, so-called, was really discovered by Titius of Wittenberg, and is, after all, merely a curious coincidence, an empiric formula, and not a real law. It was published in 1772, and may be summed up briefly thus: Take the numbers 0, 3, 6, 12, 24, and so on, and add to each of them 4. The sums thus obtained very nearly represent the relative distances of all the planets from the Sun, except Neptune. At a distance corresponding to twenty-eight—the fifth number—there is no planet, the planetoids, it may be noted, occupying its place.

In 1800, several continental astronomers formed an association to search for a planet where Bode's Law indicated there should be one. Their operations were anticipated, however, by the discovery on January 1, 1801, of a small body—the first planetoid—by the Sicilian astronomer Piazzi at Palermo, while making observations for his well-known catalogue of stars. The planetoid was found wandering on slowly in the constellation Taurus, at about the exact distance necessary to fill the gap in Bode's series. It was named Ceres after the tutelary goddess of Sicily. In March, 1802, Olbers, of Bremen, discovered a second planetoid wandering in the same regions as Ceres, which he named Pallas, and in 1804 Harding found a third which he called Juno. In March, 1807, Olbers detected a fourth, in the constellation Virgo, which he named Vesta. In 1845 a fifth planetoid was picked up by Hencke, a Prussian amateur, which received the name of Astrea, and in 1847 three more were added to the list. To-day, about eight hundred are known, and their real number seems to be legion. New ones are found frequently on the photographic plate.

The four earlier discovered planetoids, namely, Ceres, Pallas, Juno, and Vesta, are the largest, and are the only ones which actually show measurable disks. According to Barnard's measurements made in 1895 with the Lick telescope, Ceres is 477 miles in diameter, Pallas 304 miles, Vesta 239 miles, and Juno 120 miles. Vesta is the brightest of the four, and is the only planetoid that at times comes within the limit of visibility. Aside from these, none of the planetoids are larger than twenty-five miles in diameter, and most of them are much less, varying it may be from fifteen to ten miles across. All of the planetoids travel direct

like the planets, but their orbits are in many cases much more eccentric, and more inclined to the ecliptic, than are any of the planetary orbits. They cross and recross each other's path undisturbed. Only two of the orbits, so far as is known, pass beyond the orbit of Jupiter, though several cross the orbit of Mars. The nearest planetoid to the Sun is the tiny body Eros, which revolves around that luminary in 642.84 days, or 1.76 years, while the most distant one is Hector, with a period of 12.1 years.

After the four principal planetoids, the only one of special interest or importance is Eros. It was photographically discovered in August, 1898, by Witt of the Urania Observatory, Berlin, and is thought to be not a sphere but a jagged mass. Its diameter is estimated at not more than twenty miles, and it is supposed to complete a rotation on its axis in five and a half hours. Its mean distance from the Sun is about 135,000,000 miles. Its orbit is so eccentric that at intervals of about thirty-seven years it approaches to within 14,000,000 miles of the Earth, nearer than any other celestial body except the Moon or a chance comet. At such oppositions it appears as bright as a sixth- or seventh-magnitude star. The last close opposition occurred in 1894, and the next one will take place in 1931.

In February and March, 1901, about three years after its discovery, Von Oppolzer found Eros to be variable, in a period of two hours and thirty-eight minutes. At its minimum it was less than one-third as bright as at its maximum. Then in May the variation vanished. Similar periodic variability, though less marked, has been detected in Sirona, Hertha, Tercidina, and some other of the smaller planetoids. No satisfactory theory has yet been advanced to account for these variations.

Eros is of great importance in astronomy as affording, at its favourable oppositions, an opportunity for accurate determination of the solar parallax.

In mythical story, Ceres was the goddess of the growing vegetation, and was supposed to preside over the harvests.

> Ceres was she who first our furrows ploughed,
> Who gave sweet fruits and every good allowed.
>
> POPE.

She was the daughter of Rhea and Saturn, and sister of Jupiter. Among a variety of other titles she was called the *Bona Dea*, the beneficent goddess. Angered at the carrying off of her daughter Persephone by Pluto with the consent of Jupiter, she avoided Olympus, and dwelt upon the earth, and would not allow it to produce any fruits until it was arranged that Persephone should spend two-thirds of the year with her. Her feast, the Cerealia, was celebrated on April 19th, honouring the young vegetation. In works of art Ceres is represented sometimes in a sitting posture and sometimes riding in a chariot drawn by horses or dragons, but always in full attire. She wore around her head a garland of corn-ears, or a simple riband, and held in one hand a lighted torch, and in the other a poppy, which was sacred to her. Pallas was an epithet of Athena (Minerva), the reputed goddess of wisdom and scientific warfare. The goddess was the daughter of Jupiter, from whose brain she is fabled to have sprung, with a mighty war-shout, completely armed, and brandishing a spear. Juno, the queen of heaven, and goddess of the atmosphere and of marriage, was a daughter of Rhea and Saturn, and sister and wife of Jupiter.

> . . . Juno, who presides
> Supreme o'er bridegrooms and o'er brides.
> VIRGIL (Conington's tr.).

Her marriage to Jupiter, called the "Sacred Marriage," was represented in many places where she was worshipped. At her nuptials all the gods honoured her with presents. She was, properly speaking, the only really married goddess among the Olympians. Like Saturn, she was the guardian of the finances, and, under the name of Moneta, she had a temple on the Capitoline Hill, which contained the mint. Vesta, one of the great Roman divinities, was the goddess of the hearth and its fire. She was the daughter of Rhea and Saturn, and was looked upon as the giver of all domestic happiness. She was the reputed goddess of chastity, and was represented in her temple, which stood in the Forum, by no statue, but a sacred fire was maintained on her altar, which was carefully attended to by the *Vestals*, her virgin priestesses. The Vestalia, or festival of Vesta, was one of the most welcome and universally popular summer festivals of the Roman people. The little Eros was the god of love, the most handsome and lovely of the gods. By Hesiod he was represented as one of the great cosmogonic powers, along with Chaos, Gæa, and Tartarus, but by later writers as the son of Aphrodite (Venus), equivalent to the Latin god Cupid. He is generally represented as a beautiful child with golden wings, and carrying a bow and a quiver of arrows. His chief characteristic, aside from youthfulness, is the power of inspiring the passion of love. He is the usual companion of his mother Aphrodite, and is one of the characters in the profoundly thoughtful myth of Amor and Psyche.

CHAPTER IX

JUPITER AND SATURN

OMITTING the group of planetoids, the fifth planet in order from the Sun is the pale primrose planet Jupiter, the giant planet of the solar system. It is 1309 times the size of the Earth, and is larger than all the other planets put together. Furthermore, its mass is 318 times the Earth's, or more than double as large as the combined mass of all the other planets. Its surface gravity is 2.65 times that of the Earth, and its average density a little less than one-quarter of the Earth's, or only fractionally greater than that of water. In form it is an oblate spheroid, the oblateness ($\frac{1}{17}$)—a result of the planet's swift rotation—being much greater than that of any other planet except Saturn. According to Barnard's measures its equatorial diameter is some 90,190 miles and its polar diameter some 84,570 miles, a difference of 5620 miles. It travels round the Sun in a period of 11.86 terrestrial years (eleven years, ten months, and fourteen days)—a Jovian year—at a mean distance of 483 million miles, and at an average speed of eight and one-tenth miles a second. Its orbit, which is considerably more eccentric than those of Venus and the Earth, is such that its distance from the Sun varies from 462 millon miles at perihelion, to 504 million miles at aphelion. At a favourable opposi-

tion the planet's distance from the Earth is about 369 million miles, while at conjunction it is about 596 million miles.

Its synodic period is about 399 days, or a little more than a year and a month. Thus the last opposition occurred early in July, 1913, and the next will occur during the second week in August, 1914, at which time the planet will be in Capricornus, and will be a brilliant object in the summer sky. The planet will be in opposition soon after the middle of September in 1915, near the last of October in 1916, and about the first of December in 1917, and for the next few years it will be a winter star. In 1915, it will be situated on the eastern edge of the constellation Aquarius, in 1916 on the eastern border of Pisces, and in 1917 in the constellation Taurus. Jupiter's pace eastward through the zodiac is slow and majestic, being at the rate of one sign a year, or about two and a half degrees a month. For about two months before and after each opposition, the planet retrogrades, the apparently backward movement—caused by the Earth passing it in eastward motion—amounting to about ten degrees.

Its period of rotation on its axis has been found to be on the average nine hours and fifty-five minutes. Some markings, the equatorial, give a period of nine hours and fifty minutes, while others, midway between the equator and the poles, give a period some five to seven minutes longer. As stated by Stanley Williams of Brighton, England, no fewer than nine different rates of rotation of the different parts have been observed. The bright white spots seem to rotate more rapidly than do the darker markings, and on the whole the parts move faster in the southern than in the northern hemisphere. The equatorial parts, as a rule, rotate

the most rapidly, the rate of rotation being about thirty thousand miles an hour.

The inclination of the axis of the planet to its orbit is only three degrees, consequently there can be little variety in the seasons. As Jupiter is a little over five times as far from the Sun as the Earth is, it receives from that luminary twenty-five times less light and heat than does the Earth. According to the measurements of Müller at Potsdam in 1893, the albedo or reflective power of the far-away planet, as a whole, is seventy-five per cent. of the sunlight which falls upon it, which is practically the same as that of newly fallen snow.

By the spectroscope, Jupiter is shown to be surrounded by an extremely thick and dense atmosphere, heavily laden with vapour, and sometimes estimated as a thousand miles in depth. The interior of the planet is thought to be so intensely hot that the vapours driven upwards from the heated mass underneath, are kept suspended in the atmosphere in the form of dense, cloud masses—the Jovian "self-raised, not sun-raised"—clouds. That the planet has a small solid nucleus is quite probable, but there is no certainty that the body is so far cooled as to have a solid surface. The temperature of the whole planet is doubtless exceedingly high, though hardly sufficient at the surface to make the globe self-luminous. The great planet is looked upon as a sort of "semi-sun"—a sun which has just ceased to shine by its own light. It probably gives out an appreciable quantity of heat, and may have a dull red glow, but radiates no sensible quantity of light. In the earlier stages of its existence, when it shone with its own light, it doubtless presented the appearance, from outer space, of a minute companion star of the sun, the two forming a fine double star. Like the

Lick Observatory

PLATE XXXVI. The Planet Jupiter, Showing the Red Spot and a Satellite

(The image is inverted as in astronomical telescopes. The oval marking on the upper left-hand portion of the disk is the Red Spot. The round black spot to the right is the shadow of the Satellite)

rest of the major planets, it is much too young in world evolution to admit of life of any kind.

When seen through a telescope, Jupiter is one of the most beautiful and interesting objects in the heavens (Plate XXXVI.). Its broad, bright disk is distinctly oval, and displays many conspicuous and variable markings, spots, and belts. While to the naked eye its light has a slightly yellowish tint, and is remarkably steady and commanding, under telescopic view it shows a variety of beautiful colours, with the reddish ones most conspicuous. Stretching across the yellow globe from side to side are a series of broad dusky bands called belts, alternately light and dull brown, running parallel with the equator. These belts, which are belts of cloud, vary greatly both in width and number. As many as twenty or thirty have been seen at one time, but usually the number is much less. They are generally from one thousand to ten thousand miles in width, and are most conspicuous near the equator.

Situated, one on each side of the equator, are two wide and very distinct belts called the "tropical belts." They are commonly of a reddish-brown colour, though, not infrequently, a reddish-brown belt may be seen on one side of the equator, and a grey-blue one on the other. Between the tropical belts is the bright equatorial belt, a pale yellow or sometimes ruddy belt from eight thousand to ten thousand miles wide. While the Jovian belts are not permanent markings, but change in shape and detail frequently, these three are a semi-permanent feature, often remaining unchanged for a considerable time. To the north and south are other narrower belts of different colours, and often the poles are covered with hoods of pale blue or grey. Dusky or white spots also appear upon the planet's surface, which

may change in colour, shape, or brightness, or even disappear altogether for a time. All the markings, light as well as dark, lie low down in the planet's atmosphere, and, as viewed from the earth, there seems to be no great difference of altitude between them.

The most noticeable bright spot is the famous "Great Red Spot" which is situated just below the southern tropical belt (Plate XXXVI.), at about thirty-five degrees south latitude. It is one of the most puzzling and interesting features of the planet. Between the years 1663 and 1708, it appeared and vanished eight times. It became very conspicuous in July, 1878, and was then of a pale pink colour, which gradually deepened until it became a dull brick-red. As recorded by Pritchett it was an immense oblong marking, measuring about thirty thousand miles from east to west, and seven thousand from north to south. Its area was greater than that of the entire terrestrial globe, and it apparently moved independently of the planet. Six years later it had almost disappeared, but in 1890 it again became distinctly visible, though it never recovered its original bright colour. A curious phenomenon was witnessed in 1891, when the red spot was overtaken by a dark spot, which, instead of colliding or going over or under it, drifted around its southern edge. Since that time it has varied greatly both in colour and brightness, but is still faintly visible, its location being clearly indicated by an enormous bay in the outer border of the great southern belt. The nature of this wonderful spot remains as yet unknown.

So far as is known, Jupiter is attended by nine satellites, four large and five small, which are believed by W. H. Pickering to be elliptical. The four large Jovian satellites, which are almost of planetary dimensions,

were discovered by Galileo, at Padua, on January 7, 1610, with his newly-invented, but crude, telescope, and were named by him the "Medicean Stars," in honour of his patron Cosmo de Medici. They are nearly in line with the planet's equator and are easily within the range of a good opera-glass or prism binocular. The other five have been found only within the last few years, and are so extremely small and faint that they are visible only in the most powerful telescopes. It may here be noted, that the real inventor of the telescope was Franz Lippershey, a spectacle-maker at Middleberg, and that Galileo's first telescope, though an independent invention, was suggested by the Hollander's achievement.

The four large satellites are sometimes known by the names of Io, Europa, Ganymede, and Callisto, though they are more frequently designated, in the order of their distance from the planet as I, II, III, IV. Of this quartet, satellite I, with a diameter of 2450 miles, revolves around Jupiter at a mean distance of 261,000 miles, in one day, eighteen hours, and twenty-eight minutes. As a result of its rapid motion, it changes nightly, from side to side of its primary. Satellite II, the smallest of the four, with a diameter of 2045 miles, revolves in three days, thirteen hours, and fourteen minutes, at a mean distance of 415,000 miles. Satellite III, the largest of the four, with a diameter of 3550 miles, makes a complete revolution in seven days, three hours, and forty-two minutes, at a mean distance of 664,000 miles. Satellite IV, with a diameter of 3345 miles, revolves round the primary in sixteen days, sixteen hours, and thirty-two minutes, at a mean distance of 1,167,000 miles. On satellites I, III, and IV, equatorial belts and bands have been observed.

After Galileo's four moons, no other satellite of Jupiter was discovered until 1892, when on September 9th, that most thorough and reliable observer Barnard, then at the Lick Observatory, found the fifth satellite, which became designated by the numeral V. It is one of the smaller members of the Jovian system of moons, and is the nearest satellite to Jupiter. It has an estimated diameter of about one hundred miles, and revolves round its primary in 11 hours, 57 minutes, and 22.6 seconds, at a mean distance of 112,500 miles. It is notable as moving faster than any other satellite in the solar system, its orbital speed, owing to the great attractive power of the giant planet, being sixteen and a half miles a second. By the aid of the photographic plate, Perrine, at the Lick, discovered satellite VI in December, 1904, and satellite VII in February, 1905. The former, with an estimated diameter of not more than one hundred miles, revolves round Jupiter in about 242 days, at a mean distance of 6,968,000 miles, while the latter, with an estimated diameter of only thirty-five miles, completes a revolution in about two hundred days, at a mean distance of 6,136,000 miles. In February, 1908, satellite VIII, which is of the seventeenth magnitude, was discovered by Melotte, at Greenwich, with the aid of photography. It is supposed to have about the same diameter as satellite VI, and completes a revolution, in a very eccentric orbit, in a little more than two years and two months, at a mean distance of about fifteen million miles. In July, 1914, satellite IX was discovered by Nicholson at the Lick. It is of the seventeenth magnitude, and has a period of two and one-sixth years. The motions of satellites VIII and IX seem to be "retrograde," or opposite to those of the other satellites.

Jupiter is ever full of interest and charm to the amateur, as there is always something happening either on the giant world itself or among its spry and fascinating attendants. To watch the four larger satellites in their occultations, when they pass behind the planet's disk, or in their eclipses when they enter the great cone of shadow cast by the enormous globe, or most of all in their transits across the great planet's bright face, is a source of never-ending pleasure. Ordinarily, when a satellite is in transit, it will be followed or preceded, according to the season, by its shadow, the satellite being generally seen projected on the face of the planet as a brilliant white spot, and the shadow as a tiny round black dot (Plate XXXVI.). The transit of a shadow may be seen even with a two-inch telescope, but for the transit of the satellite itself a three-inch is required. Sometimes all four satellites disappear from view, as happened on October 3, 1907, when satellites I (Io) and III (Ganymede) were eclipsed, satellite IV (Callisto) was occulted, and satellite II (Europa) was in transit, and became invisible, being merged in the greater brightness of the central portion of Jupiter's disk. The times of all the transits, eclipses, and occultations are given in the *Nautical Almanac*, in which also the relative positions of the satellites from night to night are set forth. It was through observations of the transits of Jupiter's satellites that the Danish astronomer Roemer, in 1675, discovered the velocity of light, which up to that time was thought to be instantaneous, but which is now known to be approximately 186,400 miles a second.

Being regarded by the ancients as the chief of the planets, this mammoth globe was given the name of the chief of the gods, who, among the mythologists, was

Jupiter or Jove, the reputed son of Saturn and Rhea, and brother and husband of Juno. The god Jupiter, according to fable, was born and reared on Mount Ida in Crete, and reigned on the top of "many-peaked Olympus," on the coast of Thessaly. He was the chief of the gods of ancient Rome, and was identified with the Greek Zeus, the most prominent and powerful of all the Olympian divinities. When quite young, he rescued his father Saturn from the Titans, and afterwards, with the help of Hercules, defeated the Gigantes or giants, when they made war against heaven. Later he supplanted his father as ruler of the universe, and divided the empire of the world with his brothers, reserving the kingdom of heaven for himself, and giving the empire of the sea to Neptune, and that of the infernal regions to Pluto. He was generally represented as a majestic personage with long, curling hair and beard, clad in flowing drapery, and seated upon a magnificent throne of gold or ivory, with thunderbolts in one hand ready to be hurled, and a sceptre of cypress in the other, while close beside him stood an eagle with expanded wings, the emblem of strength and power.

> He whose all-conscious eyes the world behold,
> The eternal Thunderer sat, enthroned in gold,
> High heaven the footstool of his feet he makes,
> And wide beneath him all Olympus shakes.
>
> HOMER (Pope's tr.).

The worship of Jove was well-nigh universal, and surpassed in solemnity that of all other deities. According to the belief of the Romans, he determined the course of all human affairs, and by his own choice assigned good or evil to mortals. The Fates and Destiny alone dared oppose his sovereign will. He

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PLATE XXXVII. The Planet Saturn and Its Rings
(Showing wisps)

revealed the future to man through signs in the heavens, and the flight of birds. He had many oracles of which the most renowned were those of Dodona in Epirus and Ammon in the Libyan Desert. A magnificent temple at Olympia, in the Peloponnesus, was dedicated to him, where every fifth year the people of Greece were wont to assemble to celebrate games—the Olympian Games—in honour of his great victory over the Titans. He had also a splendid fane in the isle of Ægina. In Homeric poems Jupiter is described as the thunderer, the gatherer of clouds, and the originator of all atmospheric changes.

SATURN

The second largest planet in the solar system, and at the same time the most interesting, is the wonderful and beautiful ringed world, Saturn (Plate XXXVII.). It is the sixth planet in order from the Sun, and the most remote world known to the ancients. It shines with a steady, dull, red-yellow light, and to the unaided eye appears about as bright as a first-magnitude star. It is the most spectacular of all the planets, and is distinguished from all known celestial bodies by its marvellous system of immense rings, which has been known to astronomers for a little over two and a half centuries, and may be distinctly seen in a telescope of only 2½-inch aperture. It is about 740 times larger than the Earth, but is only about ninety-five times as heavy. Its density is less than one-eighth that of the Earth, or about seven-tenths that of water, or, roughly speaking, about that of cork. In proportion to its size, therefore, Saturn is the lightest of all the planets, and is probably a vast mass of seething vapours, with a com-

paratively small, intensely hot, and relatively condensed nucleus.

According to Barnard's measures, its mean diameter is 73,120 miles, but it is so flattened at the poles and bulged at the equator that the polar diameter is only 69,770 miles, while the equatorial diameter is 76,470 miles, a difference of 6700 miles. So, its oblateness or polar compression, which amounts to about $\frac{1}{11}$, is greater than that of any other planet. Its average period of rotation on its axis is ten hours, fourteen minutes, and twenty-four seconds; different portions, as on Jupiter, rotating at slightly different speeds.

Saturn revolves about the Sun in an orbit a trifle more eccentric than that of Jupiter, at a mean distance of 886,000,000 miles, in a little less than twenty-nine and a half terrestrial years (29.46 yrs.),—a Saturnian year—at a velocity of about six miles a second. Its distance from the luminary varies between 911,000,000 miles at aphelion, and 861,000,000 miles at perihelion. From the Earth the planet's distance varies between 1,028,000,000 miles at the most remote conjunction, and 744,000,000 miles at the most favourable opposition. Its synodic period, the interval from opposition to opposition, is 378 days, so that the planet returns each year about thirteen days later than the year previous. It travels eastward along the ecliptic about one degree a month, and remains, on an average, for nearly two and a half years in each constellation. Once each year, when in opposition, a slight apparent retrograde motion of some five degrees occurs, due to the Earth's overtaking and passing the planet.

The planet was in opposition December, 1913, in the constellation Taurus, and the next opposition will occur during the third week in December, 1914, when the

Yerkes Observatory

PLATE XXXVIII. The Planet Saturn

(Rings on edge, showing condensations)

planet will be about on the border line between Taurus and Gemini, and will be at its brightest. It will be in opposition again the first week in January, 1916, about the middle of January, 1917, and near the last of January in 1918. In 1916 and 1917 it will be in the constellation Gemini and in 1918 in Cancer. The ring will be open to its greatest possible extent in 1914, when its southern side will be shown, while in 1928 the northern side of the ring will be shown open at its widest. The planet is brightest when in the most easterly part of Taurus and in Scorpio, when the ring system is widest open, and least bright when in the last half of Leo and in Aquarius, when the ring appears edgewise (Plate XXXVIII.), and is so thin as to be invisible except with powerful telescopes.

Saturn's disk like that of Jupiter is darkest at the edges, and shows a number of belts and markings. The belts are parallel with the equator, but are by no means so definitely outlined, or so varied in colour, as those of Jupiter. The equatorial belt is brighter than the rest, and often shows a faint rose-coloured tint, while the tropical belts are of a grey-green shade, and the polar regions of a leaden colour. At times brilliant white spots appear upon the surface, and remain visible for a number of weeks. The axis of the planet is inclined from a perpendicular to the plane of its orbit about 27°, consequently the seasons are similar to those of the Earth, though longer and much more accentuated, each season lasting more than seven terrestrial years. The planet's supply of solar light and heat is only about one-ninetieth of that received by the Earth, but the globe is probably intensely hot in itself, and has an exceedingly luminous, dense, and cloud-laden atmosphere. As with Jupiter, the heat which raises the

clouds comes from the planet itself and not from the Sun. Did the planet depend on the Sun alone for heat, its temperature would be not far from three hundred degrees below zero, Fahrenheit.

The most striking and unique feature of Saturn is the system of rings which girdles its equator, and which was first glimpsed by Galileo in 1610, but was first observed in its true form by Huyghens in 1656. The rings are three in number, and are generally referred to as A, B, and C,—A being the outer ring. They lie one within the other in the same plane, and are so extremely thin that their estimated thickness is not more than eighty miles. They revolve around Saturn in the same direction as the planet rotates on its axis. Though apparently elliptical in form, they are really circular, their elongated appearance being due to the angle at which they are seen from the Earth. They do not shine of themselves, but receive their light from the Sun, and as G. H. Darwin, son of Charles Darwin the great biologist, suggested, probably represent merely a passing stage in the evolution of the Saturnian system. Somewhat recently Lowell has drawn attention again to beads on the rings, which are thought to be points of collision of the fragments of matter composing them.

According to Barnard's measures, the exterior diameter of the outer ring, Ring A, is approximately 172,600 miles. Its width is 11,060 miles, and it is divided into two nearly equal parts by the so-called "Encke's division." It is separated from the middle ring, Ring B, by a dark space, known as "Cassini's division," which is sharp and distinct, and has a width of 2240 miles. This division was discovered in 1675, by the celebrated French astronomer, G. D. Cassini, the first director of the Paris Observatory. Ring B is

nearly eighteen thousand miles in width, and is the brightest of the three. Near its outer edge it is brilliantly luminous, but at its inner edge it fades into the inner ring (Ring C) which is but slightly luminous, and is sometimes called the crêpe or gauze ring. Ring C is 10,900 miles in width, and is nearly six thousand (5865) miles distant from Saturn. It has a dusky, greyish appearance, and is semi-transparent, the curve and body of the planet being visible through it. It was discovered by W. C. Bond of Harvard in 1850. Neither it nor Encke's division can be seen except in the largest telescopes. The rings of Saturn are believed to consist of myriads of meteoric particles, each circling in its own individual orbit, but all keeping so close together that they appear like three solid concentric rings, whirling continually around the great planet. According to the laws which govern planetary bodies, the particles which are nearest the planet move most rapidly, and those which are farthest move most slowly. With the aid of the spectroscope, Keeler, in 1896, found that the outside of the ring was moving at the rate of ten miles a second, and the inside at the rate of twelve and a half miles in the same period of time.

In addition to the rings, Saturn has ten satellites, which, so far as is known, is more than any other planet of the solar system possesses. They all revolve outside the rings, and with the exception of Iapetus and Phœbe, revolve nearly in the plane of the rings. Their names in order of their distance from Saturn are: Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Themis, Iapetus, and Phœbe. Of these only Titan and Iapetus are visible in small telescopes, the others requiring powerful instruments. Titan, the largest and brightest of the satellites, has a diameter of 2720

miles, and was first seen by Huyghens in 1655. It is 771,000 miles distant from the planet, and has a period of fifteen days, twenty-two hours, and forty-one minutes. Iapetus with about two-thirds the diameter of Titan, is 2,225,000 miles distant from Saturn, and has a period of about seventy-nine days and eight hours. It was discovered by Cassini in 1671, and seems to be much brighter on one side than the other. Rhea, the third brightest moon, with a diameter of some 1500 miles, is 332,000 miles distant. Mimas, the closest to Saturn of the ten, with a diameter of some 600 miles, is 117,000 miles distant, and revolves about that planet in twenty-two hours and thirty-seven minutes. Hyperion revolves in a very eccentric orbit, at a distance of 934,000 miles. Dione, 238,000 miles distant, and Tethys 186,000 miles, were both discovered in 1684 by Cassini. Enceladus, with a distance of 157,000 miles, was, together with coy Mimas, discovered by Sir William Herschel, in 1789. Phœbe, with an estimated diameter of 150 miles, is 7,996,000 miles distant from its primary, and has a period of rather more than 546 days. It is a remarkable and independent little moon circling in an eccentric orbit in a "retrograde" direction, that is, from east to west. It is the ninth satellite, and was found by photography, by W. H. Pickering in 1899. The tenth of Saturn's train of satellites, Themis, also a photographic discovery, is 906,000 miles distant from the planet. It is a tiny body, with an estimated diameter of not more than forty miles, revolving round its primary in approximately twenty-one days. It was found by W. H. Pickering in 1905.

In mythology, Saturn or Cronos, the youngest of the Titans, was the son of Uranus and Gæa, and father of Jupiter, Neptune, Pluto, Juno, etc. He was King of

Plate XXXIX. The Eight Columns of the Temple of Saturn at Rome

the Universe, and was worshipped by the Romans even in their prehistoric days, but his temple was not erected on the Capitoline until 498 B.C. The original Temple of Saturn was built by the Tarquins, and was supposed to mark the site of the Sabine altar to the god, and the limit of the wood of refuge mentioned by Virgil. It was the only temple in Rome where heads were uncovered, and tapers were first introduced in Roman religious ceremony in this fane.

Next to the Temple of Vesta, that of Saturn is the oldest in Rome. "Its beginnings," says F. Marion Crawford, "are lost in the dawnless night of Time—of Time who was Kronos, of Kronos who was Saturn, of Saturn who gave his mysterious name to the Saturnalia"—festivals which were celebrated as a harvest-home observance, about the time of the winter solstice—"in which Carnival had its origin." Before this temple Pompey sat surrounded by soldiers, listening to Cicero's defence of Milo, when he received the personal address, *Te enim jam appello, et ea voce ut me exaudire possis.* (Ciceronis Pro Milone Oratio, Ch. XXV.)

The temple was restored in the early years of the reign of Augustus, and again, as the inscription on the entablature tells, in A.D. 283. Eight granite Ionic columns (Plate XXXIX.) still stand upon a part of the foundation, and these with some steps, that perhaps led to the "Ærarium," or Treasury of Rome, are all that can be seen of the ancient shrine. Saturn was known as the god of time, and was portrayed as a decrepit old man, with sickle and hour-glass. The Golden Age is said to have been during his reign, when according to Hesiod,

> Men lived like gods, with minds devoid of care,
> Away from toils and misery.

CHAPTER X

URANUS AND NEPTUNE

REVOLVING around the Sun as its seventh planet is the huge globe Uranus, to which belongs the distinction of being the first world discovered in historic times. It was found accidentally by the elder Herschel (William), an amateur astronomer, and organist of the Octagon Chapel at Bath, England, on March 13, 1781, while examining the small stars near Eta Geminorum. Strange to say, it had been seen many times before Herschel's discovery, but on account of the slowness of its motion had been catalogued as an ordinary star. Herschel proposed to name the new planet Georgium Sidus—the Georgian Star—after his patron, the penurious monarch "Farmer George," who had bestowed on him knighthood and the not very magnificent pension of two hundred pounds a year. Later, however, it was known as Herschel, and finally, on the suggestion of Bode, as Uranus, its present classical title. On a clear and moonless night, when near opposition, it looks as bright as a sixth-magnitude star, and can be detected with the unaided eye, when the observer knows where to look for it. An opera-glass or prism binocular field-glass will show it quite well. In the telescope it appears as a pale, greenish-blue, disk, traversed by some faint markings.

The planet's mean distance from the Sun is 1,782,000,000 miles, and the eccentricity of its orbit is somewhat less than that of Jupiter, but more than that of Neptune. Its diameter is 31,900 miles, and it completes a revolution around the Sun in about eighty-four terrestrial years (84.02 yrs.), at the rate of a little over four miles a second. The inclination of its equator to the plane of its orbit is about ninety degrees. It rotates like a top rolling on its side, in a period of some ten or twelve hours, and in that position travels along its vast orbit, which deviates less than half a degree from the line of the ecliptic. It rotates in a "retrograde" or backward direction, but it revolves in the direction pursued by all the other planets, a direction called "counter-clockwise." Its volume is about sixty-five times that of the Earth, while its mass is only about fourteen and a half times the Earth's mass. It is about one-fifth as dense as the Earth, and its force of gravity is about nine-tenths that of the Earth. It is probably in much the same vaporous state as Jupiter and Saturn, and is in a condition of great heat. From observations made at Lowell Observatory it is inferred that it has an extensive atmosphere made up largely of light gases. According to Müller its mean albedo, or intrinsic brightness, is 0.73, or almost that of cloud.

The synodic period of the planet is some $369\frac{1}{3}$ days, so that oppositions occur only four or five days later each year. Thus it was in opposition in 1913 on July 29th, and will be in opposition again on August 2d, 1914, August 6th, 1915, and so on. Uranus remains in each constellation about seven years, and is now in Capricornus, about twenty-four degrees east of the Milk Dipper in Sagittarius. Its advance among the stars amounts to a little over $4\frac{1}{4}$ degrees a year.

The planet has four satellites, known as Ariel, Umbriel, Titania, and Oberon. Titania and Oberon were discovered by Herschel in 1787, while Umbriel and Ariel were discovered in 1851, the former by Struve, and the latter by Lassell. These four satellites are all comparatively small bodies, less than a thousand miles in diameter, and are remarkable, in that their orbits are almost perpendicular to the plane of the planet's orbit, and that the motions of all of them are "retrograde." The backward direction of the satellites is, however, from north to south, with a slight inclination westward. Ariel the nearest satellite revolves round Uranus in two days and twelve hours, at a mean distance of 120,000 miles; Umbriel in four days and three hours, at a mean distance of 167,000 miles; Titania, in eight days and sixteen hours, at a mean distance of 273,000 miles; and Oberon in thirteen days and eleven hours, at a mean distance of 365,000 miles. Titania is larger than Oberon, while Ariel and Umbriel are both smaller than either of them. Under favourable conditions, the two former are visible in a six-inch telescope, but the two latter can only be seen in the largest instruments.

In classical mythology, Uranus or Ouranus, was the son of Gæa, the Earth, and father of the Titans, Cyclopes, and Giants, all personages of great renown. According to the Greek poets, with him began the first race of gods. He hated his children, and fearing to lose his kingdom by their violence, cast them into Tartarus, and kept them prisoners. At the instigation of Gæa, and headed by Saturn, they rose against him and overthrew his rule. The government of the world was then given to Saturn, who in his turn lost it through his son Jupiter, as was predicted to him by Uranus and Gæa.

NEPTUNE

The outermost planet of the solar system, so far as is known, is Neptune, the eighth planet in order from the Sun, and the third in mass and volume (Plate XL.). It was discovered by calculation, and its discovery is regarded as one of the greatest triumphs of mathematical astronomy. From slight irregularities in the movements of Uranus, amounting to about $1\frac{3}{4}$ minutes, two young, able men—J. C. Adams, of England, and U. J. J. LeVerrier, of France—independently calculated where the unknown disturber (a planet) ought to be. Adams finished his results first, in October, 1845, and communicated them to the Astronomer Royal, Airy, asking that the planet be searched for. No active steps, however, were taken in the search, by the British official astronomers, until the following summer. Meanwhile LeVerrier finished his computations, and sent the results to the young German observer Galle at the Berlin Observatory, of which Encke was the director. On September 23d, 1846, the very first night after receiving LeVerrier's letter, Galle began the search, and found the perturbing planet within less than a degree of the spot designated by LeVerrier. Hence it appears that but for the official slackness of the British astronomers in the use of Adams's computations, the planet might have been seen months before. The honour of the discovery is to-day given equally to Adams and LeVerrier. At first, the newly-discovered body was called LeVerrier, but was later, at the suggestion of LeVerrier, and in keeping with the custom of naming the planets after the Olympian deities, given the name of Neptune. Since its discovery it has been ascertained that it had been seen for more than half a century, but had been taken for

an ordinary star. It is as bright as an eighth-magnitude star, and though invisible to the naked eye can be seen in a good prism binocular. In a telescope of considerable power its disk appears of a bluish or leaden tint.

The mean distance of Neptune from the Sun is 2,791,500,000 miles. Its orbit is less eccentric than that of any other planet except Venus, but the eccentricity is nevertheless sufficient to make its distance vary some fifty million miles. It revolves around the Sun "direct" (that is from west to east), as all the other planets do, in a little less than one hundred and sixty-five (164.78) terrestrial years, at the rate of $3\frac{3}{8}$ miles a second. The diameter of the planet is nearly thirty-five thousand (34,800) miles. Its axis is even more tilted over than that of Uranus, and its "retrograde" motion thereon is pronounced. Its rotation period is not known, but it is thought to be short. Its volume is nearly one hundred times that of the Earth, and its mass about seventeen times the Earth's mass. Its mean density (0.20) is somewhat less than that of Uranus. The solar light and heat it receives are but one nine-hundredth part of what the Earth takes. Owing to its immense distance and small apparent size practically nothing is known of its surface details.

Neptune changes its position in the sky rather more than two degrees a year, and remains on an average about thirteen years in each constellation. Since its discovery, it has passed through the constellations Aquarius, Pisces, Aries, Taurus and Gemini, and is now in Cancer. It will be in opposition on January 16th, 1914 and oppositions will occur about two days later each year thereafter.

PLATE XL. The Planet Neptune and its Satellite

So far as is known, Neptune is attended by but one satellite (Plate XL.), which was discovered by Lassell, an English amateur astronomer, on October 10, 1846, and appears as a star of about the fourteenth magnitude. It has an estimated diameter of about two thousand miles, and is situated at a distance of about 223,000 miles from the planet, around which it revolves in five days, twenty-one hours, and eight minutes, which constitute a Neptunian month. Like the Uranian moons, this nameless satellite performs its revolution round its primary in a "retrograde" manner.

In mythological story, Neptune, after whom the planet was named, was the son of Saturn and Rhea, and husband of Amphitrite the daughter of Oceanus and Tethys. He was identified with the Greek Poseidon, and was the chief marine divinity of the Romans. By one word he could stir up or calm the wildest storm.

> He spake, and round about him called the clouds
> And roused the ocean—wielding in his hand
> The trident.
>
> HOMER (Bryant's tr.).

He is commonly represented as a bearded man of stately presence, seated in a shell chariot drawn by dolphins or sea-horses, and surrounded by Tritons and sea-nymphs, and holding in his hand a trident with which he rules the waves.

CHAPTER XI

COMETS AND METEORS

AMONG the most interesting of objects in the nocturnal sky are those mysterious, wandering bodies called comets and meteors, which from the very earliest ages have attracted widespread attention. Unlike the planets they are not confined to the limits of the zodiac, but appear in almost every quarter of the heavens. Up to the present time there have been seen and recorded some twelve hundred comets, about one hundred and fifty have been identified, and the orbits of nearly five hundred have been calculated. During the last century there were thirteen visible to the unaided eye. Some five or six comets are usually discovered each year, most of them being telescopic. They remain visible for periods varying from a few days to more than a year; including telescopic vision, the average duration of visibility is about three months. Some comets have been visible in the daytime; possibly about four or five are so visible in a century.

About eighty-five out of the several hundred comets known seem to have elliptic orbits, fourteen seem to have hyperbolic orbits, and all the others, including most of the great comets, move around the sun in sensibly parabolic orbits. Comets with exactly parabolic or hyperbolic orbits—open curves—may be regarded as

celestial messengers which visit the local solar system once, and then recede towards the infinite depth of cosmic space from which they came, apparently never to return again. Comets which move in ellipses of known eccentricity are supposed to have been drawn out of their original parabolic orbits, into elliptic orbits by the attraction of one of the larger planets. They return to the neighbourhood of the sun at short or long intervals, with periodic regularity, and may be regarded as assured members of the local solar system.

Comets whose periods are less than one hundred years are termed periodic comets. They are about sixty in number, and nearly half of them have been observed more than once. A number of the periodic comets have their orbits extending to the orbit of the giant Jupiter. Still others go as far as Saturn and Uranus, and some to Neptune. The orbits of all comets whose periods are less than eight years pass very near the orbit of Jupiter. The orbits of the seventy to eighty-year comets come very close to the orbit of Neptune. The thirty-three-year comet passes very near the orbit of Uranus. All periodic comets of less periods than eighty years follow direct motion, with the exception of Halley's comet and Tempel's comet of 1886, which have retrograde motion. The long-period comets and the parabolic and hyperbolic comets incline to retrograde motion.

Some thirty-two of the comets that travel in elliptic orbits of short periods, and of relatively small eccentricities, are known as "Jupiter's comet family," and have periodic times ranging from three to eight years. The planet Saturn has a similar family of two comets, Uranus three, and Neptune six. There is a small group of six periodic comets of between seventy and eighty

years, which have been considered as members of the local solar system, although only three of them have appeared a second time, namely Halley's, Olber's, and Pons's. These three complete their periods in years as follows: Halley's 76.68, Olber's 74.05, and Pons's 70.68. Many comets are on record with periods of from eighty to ten thousand years; a few with periods of from thirteen thousand up to nearly three million years.

Of some twenty-seven interior or short-period comets recorded, thirteen have passed their perihelion more than once. The most favourably known complete their periods in years as follows: Encke's (discovered in 1818) 3.31, Winnecke's 5.54, Tempel's 5.15, Faye's 7.44, Brooks's 7.07, Holmes's 6.85, and Tuttle's 13.66.

Formerly all cometary apparitions were taken seriously, and were thought to be signs from heaven foretelling great events in the world. Up to even Elizabethan times, it was popularly supposed that royal deaths were heralded by these strange and mysterious visitants. In *Julius Cæsar*, Shakespeare makes Calphurnia exclaim as she pleads with Cæsar, her husband, not to venture forth upon the Ides of March:

> When beggars die, there are no comets seen,
> The Heavens themselves blaze forth the death of Princes.

In the Manchester Art Gallery is the well-known picture "Beware the Ides of March," by Sir E. J. Poynter, in which the comet is depicted.

A comet—probably Halley's—sometimes called William the Conqueror's comet, which appeared in April, 1066, the year of the Norman Conquest, struck terror to the Saxons, and was regarded as presaging the success of the invasion and the death of Harold. "*Nova*

Lowell Observatory

PLATE XLI. Halley's Comet, May 13, 1910

(Venus to right. Paint line across tail near head is meteor trail)

stella, novus rex" ("A new star, a new sovereign") was the proverb of the time. In the famous Bayeux Tapestry, said to have been made as an ornament for the nave of Bayeux Cathedral, appears a representation of the comet and of the alarm and amazement of the people. The legend over the picture is "*Isti mirantur stellam.*" The piece is a long narrow strip of embroidery executed in many colours on a cream-white ground. Its length was two hundred and thirty feet, and its width only nineteen inches.

In *The Seasons*—Summer—the poet Thomson has this allusion to the apparition of a comet:

> Lo! from the dread immensity of space,
> Returning, with accelerated course,
> The rushing comet to the sun descends:
> And, as he shrinks below the shading earth,
> With awful train projected o'er the heavens,
> The guilty nations tremble.

Three years after the Turks, under Mahomet II, had taken Constantinople, and their armies were threatening to advance westward into Europe, a comet—Halley's—appeared. This was in June, 1456, when John Hunniades, the Pope's general, was defending Belgrade against the Moslem hordes. Its apparition at this time was considered a certain sign of the anger of the Almighty, and is said to have paralysed both armies with fear. A universal panic prevailed among the people, and some even thought the day of judgment (*Dies Iræ*) was at hand. There is an oft-told story of the Pope and the Comet—which has been proved to be a myth—to the effect that so alarmed had Christendom become at the simultaneous apparition of the Turk and the comet, Pope Calixtus III, great-

uncle of the notorious Lucretia and Cæsar Borgia, issued a bull against the celestial visitant, and ordered that the bells in all the churches should be rung each day at noon, and that *Ave Marias* should be repeated by the faithful everywhere three times a day instead of two, and appended this additional supplication: "Lord, save us from the devil, the Turk, and the terrifying comet."

History records that the Turks were defeated while the comet was still visible, and Mahomet was compelled to raise the siege of Belgrade; and that within ten days after its appearance the comet began to diminish in brilliancy and extent, and finally, to the great relief of Europe, it entirely disappeared. In commemoration of the great victory, comet-money was struck, some of which, it is said, is still in existence.

Maunder, in his *Astronomy of the Bible*, leans to the suggestion made by several writers that when Jerusalem was wasted by pestilence, and David offered up the sacrifice of intercession in the threshing-floor of Ornan the Jebusite, the King may have seen in the scymitar-like tail of a comet (such as the great comet of 1882), God's "minister, a flaming fire" (Psalm civ., 4), "the angel of the Lord stand between the earth and the heaven, having a drawn sword in his hand stretched out over Jerusalem" (I Chron. xxi., 16).

Milton, England's greatest epic poet, compares the cloven-hoofed Satan to a comet, and the tail is described as setting fire to the sky:

> Incensed with indignation, Satan stood,
> Unterrified, and like a comet burned,
> That fires the length of Ophiuchus huge
> In the arctic sky, and from his horrid hair
> Shakes pestilence and war.
>
> (*Paradise Lost*, Bk. II).

Further on in the same poem, when, prior to the removal of Adam and Eve, the Cherubim descend to take possession of the Garden, he makes another allusion to a comet—an allusion, perchance, supporting the idea that a comet was "the flaming sword which turned every way, to keep the way of the tree of life:"

> High in front advanced,
> The brandished sword of God before them blazed
> Fierce as a comet; which, with torrid heat
> And vapors as the Libyan air adust,
> Began to parch that temperate clime.
> (*Paradise Lost*, Bk. XII).

Among the superstitious, the comet of 1811—the most remarkable comet which has appeared in modern times, since 1680—was considered the dread harbinger of the War of 1812. It was also this comet that attracted the attention of Napoleon in connection with his invasion of Russia, and divers omens were drawn from it. Furthermore, the most beautiful comet of which there is any record—Donati's of 1858—was the accredited forerunner of the American Civil War!

By the ancients, comets were thought to be hairy objects, from the appearance of the tails, hence the origin of the term "comet," from the Greek κομήτης, signifying "long-haired." A typical comet visible to the naked eye is an illuminated, filmy object, consisting usually of three parts—the nucleus, the coma, and the tail. The nucleus and coma taken together constitute the head, which is invariably the most important part of the comet. The heads of comets vary greatly in size, being anywhere from ten thousand miles up to more than a million miles in diameter. The nucleus, which contains nearly all the mass of a typical comet, varies from one

hundred miles to over five thousand miles in diameter. The luminous train, which presents the appearance of a stream of silvery-grey light, by which most naked-eye comets are attended, and which is the chief glory of a large comet, is a continuance of the coma, and is called the tail.

Some comets have tails of enormous length, while others, a much larger number, have little or no tails. The tailed comets are frequently visible to the naked eye, while the tailless ones are not. Nearly all the large and brilliant comets have been accompanied by long tails, the tail of the great comet of 1843 being two hundred million miles long. A remarkable peculiarity of the tails of all comets is that they are directed approximately away from the sun.

The nucleus, or central part of a comet's head, is made up of meteorites, loosely packed together with wide interspaces, and various earthy substances in which hydrogen and other gases are absorbed. The meteorites may vary in size from fine dust to bodies of considerable proportion. They consist largely of iron or meteoric stone, with about five per cent. of nickel. The tails of comets consist of gaseous matter, such as hydrogen, cyanogen, and other hydro-carbon compounds, and at times, also, of vapour of sodiumand iron, mingled, perhaps, with minute solid particles, subjected to a strong repulsive force, which drives them away from the sun with enormous velocity. Nearly all of the light of comets comes from an electric illumination of the gaseous matter, which in the tail is in a highly rarefied state.

Two leading theories have been advanced to account for the tails of comets. One of these, the theory of a Russian astronomer, Bredichin, presumes an electrical

action emanating from the sun; the other, that of a Swedish scientist, Arrhenius, supposes a pressure or push of the sun's light and heat waves, termed "radiation pressure." However, as Pickering states, all that we at present know is that "it is the effect of the sun upon the comet that creates its tail; just how it acts we do not know."

The best classification of tails is that of Bredichin. He divides comets' tails into three principal types: the straight or hydrogen tail, like the tail of the great comet of 1843; the ordinary curved tail of the hydrocarbons, such as the broad streamer of Donati's comet of 1858; and the short, brush-like, stubby tails of metallic vapours. The repulsive forces in these different types are, respectively, from 12 to 15, 2 to 4, and 1.5 times that of the attractive action due to gravitation.

All the tails are hollow, luminous cones or cylinders, of which only the sides are generally visible. Every part of the comet is so transparent that even faint stars have been seen shining through the most brilliant portions, without any apparent diminution of their lustre.

A notable example of comets breaking up and disappearing is that of Biela's comet, a short-period comet which was first seen in 1826. It had an orbital period of between six and seven years, and continued to be regularly visible until 1852, when it vanished from sight in interplanetary space, and has not been seen since. In its orbit, however, travels a large meteor swarm.

Occasionally, as a result of the disturbing attraction of Jupiter, radical changes in cometary orbits have occurred, notably in the cases of Lexell's comet of 1770, and of Brooks's comet of 1886. The giant planet is said to have so wrenched the Brooks comet out of its course, "derailed it" as it were, as to change its period from twenty-seven to seven years.

Among the remarkable comets, many of which are celebrated in history, are the comet of 1680, notable as being the one to which Newton's theory of gravitation was first applied, and the great periodic comet of 1682. The latter—the most famous comet that has ever been known, and the first to make a predicted return—was discovered by Edmund Halley, and is therefore called Halley's comet. For over two thousand years it has visited the sun's domain with periodic regularity once in every seventy-five to seventy-seven years, and has been seen at least twenty-eight times by the astonished eyes of man. At its last appearance (1910), it made a rather poor display and was a disappointment to the public and astronomers alike (Plates XLI. and XLII.). It may here be noted that in comet-pictures the stars usually appear as bright streaks and not as points, for the reason that the photographic telescope is adjusted to keep pace with the comet rather than with the stars.

The great comet of 1811, to which the wonderful vintage of that year was ascribed, was a magnificent object, and was visible for nearly a year and a half. Its nucleus was four hundred and twenty-eight miles in diameter, and of a ruddy hue, and was enclosed within a nebulous globe one hundred and twenty-seven thousand miles across. The length of the tail was one hundred and thirty million miles, and its breadth nearly fifteen million miles. The following lines were addressed to it by "The Ettrick Shepherd":

Stranger of heaven, I bid thee hail!
Shred from the pall of glory riven,
That flashest in celestial gale
Broad pennon of the King of Heaven.

Yerkes Observatory

PLATE XLII. Halley's Comet, May 29, 1910
(The tail is about 8° long)

Whate'er portends thy front of fire
And streaming locks, so lovely pale,
Or peace to man or judgment dire,
Stranger of heaven, I bid thee hail!

The splendid comet of 1843 was one of the most brilliant of modern times, and also marked a rich vintage year. It came so close to the sun that the two surfaces were only thirty-two thousand miles apart. The length of its tail was about two hundred million miles.

The finest comet of the nineteenth century was the comet of 1858, called Donati's comet. It was remarkable for the intense brilliancy of its nucleus, and the magnitude and artistic conformation of its tail. It reached perihelion the latter part of September, and was visible to the naked eye for over three months. Donati's comet and DeCheseaux's of 1744, are considered the most beautiful comets on record. Tempel's comet of 1866 is unique in that it is connected with the Leonid meteors.

The next notable comet was the Great Southern Comet of 1880. It was visible, however, for but two or three weeks, and then only in the southern hemisphere. It passed through the coronal envelope, and almost grazed the sun, after which it retreated in a damaged condition, and has never appeared since. The great comet of 1882 was the most magnificent in recent years. It remained in sight about nine months brandishing a portentous scymitar-like tail, which at its best was one hundred million miles in length. It travelled in nearly the same orbit as the comets of 1843 and 1880. After it the best comet was Daniel's comet of 1907.

Morehouse's comet of 1908 (Plate XXXIII.), although only a telescopic object, early attracted a great deal of attention, owing to the transformations which it underwent. Its lightning changes of form and its periodical outbursts were most remarkable. Time and again it lost its tail and as often formed new ones. Its spectrum, which showed the presence of carbon and cyanogen, was quite different from that of previous comets.

The Daylight comet of 1910, called comet *a* 1910, was a "surprise comet." It was discovered one morning in January, 1910, by some miners in South Africa. After it passed the sun and became visible in the evening skies, it attracted much attention. Its tail reached for more than one hundred million miles across the sky.

Comet *c* 1911, one of the finest lesser comets of recent years, was discovered by Brooks at Geneva, N. Y., on July 20, 1911. To the naked eye it appeared as a hazy star, and showed its cometary character unmistakably in an opera-glass or prism binocular. In September it became a splendid object in the evening sky, a photograph, taken of it by Barnard on the 22d, showing its slender tail to be 15,000,000 miles long, and its head 500,000 miles in diameter. On October 1st, it was brighter than the fifth magnitude, and was telescopically visible during the latter half of November. On September 1, 1913, Metcalf discovered a small comet in the constellation Lynx. It was a telescopic object of about the tenth magnitude, and was known as comet *b* 1913. For more details about these filmy voyagers the reader may consult *Comets and Meteors*.

METEORS AND METEORITES

Meteors, popularly known as shooting-stars or "fiery tears," are for the most part very small bodies—

minute fragments of cometary débris—moving about in space unnoticeable, except when they come near the earth and enter its atmosphere. They are not intrinsically luminous, but the friction resulting from their rush, usually obliquely, toward the earth and through the atmosphere, at an average speed of nineteen to twenty-five miles a second, transforms the motion into heat.

The small particles of meteoric matter rapidly become incandescent, and burn like true stars with great brilliancy. Their glory, however, is but for the moment, as even their visibility portends their dissolution. Obviously the smaller ones are consumed by the excessive heat, their remains falling to the earth in ferruginous dust mixed with carbon and nickel. An occasional meteor survives the fiery ordeal, and perchance penetrates to the earth's surface. It has been calculated that every day the dust of some four hundred million meteors falls imperceptibly to the surface of the earth.

The researches of Schiaparelli, Denning, and others have shown that meteors are probably the disintegrated parts of comets which have exhausted their cometary destiny, and no longer maintain a corporate existence. They generally travel together in swarms, which circuit around the sun in elongated, elliptical paths, that resemble cometary orbits. Some of the orbits are actually those of known comets.

Meteors come from definite areas of the sky, and arrive in swarms at certain times of the year, though some may be seen almost any night. That quarter of the heavens from which a shower of meteors comes is called a "radiant." Three of the principal meteor swarms are well known and give rise to fine displays.

They are the "Leonids" and the "Bielids," which appear in November, and the "Perseids" or August meteors. The most famous of these is probably the Leonid display. It received the name Leonids, because the radiant from which the meteors seemed to diverge is situated in the head of the constellation Leo. For some thirteen centuries the maximum showers have appeared with considerable regularity every thirty-three and a quarter years. These Leonid meteors form a compact swarm, and travel along the same orbit as Tempel's comet of 1866. The grandest display was that seen in the early morning hours of November 12, 1833, when meteors fell from the starry vault numerous as the flakes of a shower of snow, and a ball of fire was seen at Niagara Falls as large as the moon. It is estimated that two hundred and forty thousand meteors appeared inside of seven hours. In 1866 the shower was abundant and brilliant, but in 1899 the display was scanty and ineffective. There is reason to believe that there are several parallel streams of the November meteors, some of which are distributed entirely around the orbit, so that about the 15th of November each year a few of them may be seen.

The "Andromedid" shower occurs between the 23rd and 27th of November. It received its name because the meteors appear to issue from the direction of the constellation Andromeda. The meteors have also been termed "Bielids," because their orbit is closely related with that of the missing comet of Biela, the disaggregated remains of which may have aided the swarm in taking on increased activity. During the Andromedid display in 1885 a meteoric mass fell at Mazapil, in northern Mexico, which some have thought may be a piece of Biela's comet. It is now in the

Museum at Vienna. It weighed about ten pounds, and was composed of iron alloyed with nickel.

The August swarm occurs on the 10th of the month, and has received the name of "Perseids," because the radiant point is situated in the constellation Perseus. It has also been called the "tears of St. Lawrence," as the feast of that saint is on August 10th, the date of the maximum shower. Its history may be traced back to 811 A.D. The orbit of this swarm is a very elongated ellipse, and has been identified with that of Tuttle's comet of 1862. The comet of 1532 also belongs to the Perseid orbit, and, if not already disintegrated, should return in 1919. The showers of the Perseid meteors are not limited to the date of August 10th to the 12th, for meteors may fall in greater or less numbers for ten days each way. These meteors travel very rapidly, and fall at the rate of about sixty an hour. Their luminous ephemeral trails often persist for a minute or two before they become disseminated.

The meteor showers of April 20th are known as the "Lyrids." They correspond in regard to their orbits with the comet of 1861, and appertain to the constellation Lyra.

Comparatively rare and startling are the objects called "fireballs" or bolides—solid meteorites of various shapes and sizes, which burn in the air during their flight. They enter the earth's atmosphere with a velocity of from twenty to thirty miles a second, and quickly become incandescent. Their speed soon moderates, so that about the time they disappear they may not be moving more than a mile a second. They generally make their appearance at an altitude of from seventy-five to one hundred miles, and are seldom visible after having descended to within five miles of the earth's

surface. Often while high up in the air they burst into luminous fragments, which, unless consumed in their flight, fall with a great rushing noise to the earth, sometimes striking with such force as to bury themselves in the ground. Not infrequently the train of sparks that usually follows a great fireball persists for a considerable time, as occurred on February 22, 1909, when a fireball, which passed over southern England, left a luminous train that remained visible for two hours, drifting and turning in the wind.

In one of Raphael's finest pictures, *The Madonna of Foligno*, which dates from 1512, a fireball may be seen beneath a rainbow, the great painter desiring thus to preserve the memory of it as it fell near Milan on September 4, 1511.

When meteors come hurtling down through the atmosphere and reach the earth, they are called meteorites, of which there are two kinds, the stony and the iron. Those containing an admixture of iron and stone are known as siderolites. The iron meteorites, or "siderites," are associated with comets, and are composed almost entirely of iron and nickel, but contain also hydrogen, helium, and carbon. The stony meteorites, or "aërolites," are many times more numerous than the iron meteorites, and move usually with terrestrial velocities, while the iron meteorites move much faster. According to Berwerth of Vienna, some nine hundred meteorites of noticeable size fall on the earth each year.

There are many remarkable stories handed down from early times of stony meteorites falling from the sky, like that of the "Nemæan Lion," or "Lion of the Peloponnesus," which, it is believed, fell out of the moon upon the isthmus of Corinth. Tradition says that the shapeless block on which Diana of Ephesus

American Museum of Natural History, N Y

PLATE XLIII. The Ahnighito Meteorite

(The great Cape York Meteorite, 10 feet 11 inches long, 6 feet 9 inches high, and 5 feet 2 inches thick)

stood was a meteoric stone. The celebrated "black stone" in the Caaba, an old temple at Mecca, and the "Palladium" of ancient Troy, which were supposed to be gifts handed down from heaven, were probably stony meteorites. The star-stone, which fell all on fire, near Egos Potamos, in Thrace, in 406 B. C., and which was described as being the size of two millstones, was one of the most famous meteorites of antiquity.

The dimensions of meteorites vary considerably, from impalpable dust to blocks weighing many tons. The National Museum at Washington contains some remarkable specimens of meteoric stones and meteoric irons. In the American Museum of Natural History, New York, is the "Long Island" meteorite, the largest *stone meteorite* known. It was found in more than three thousand pieces, and weighed a little over thirteen hundred pounds. The mass, it is thought, burst just as it struck the ground, near the town of Long Island, Kansas. Two of the best known instances of stony meteorites with high velocities are the six-hundred-and-sixty-pound one, which fell at Knyahinya, Hungary, and the seven-hundred-pound one that fell at Amana, Iowa.

In Greenland and Mexico are found quantities of meteoric iron in such masses as for years to have furnished the natives with workable iron. The first iron used was called by the Greeks σίδηρος, because it was sidereal or meteoric.

The *iron meteorite*, "Ahnighito," brought to the United States by Peary, from Cape York, Greenland, is one of the largest known. It is now in the foyer collection of the American Museum of Natural History, New York, and weighs over thirty-six and a half tons. The equally large mass, discovered at Bacubirito,

Mexico, weighs about twenty tons. The Willamette meteorite found in the forest about nineteen miles south of Portland, Oregon, in 1902, is the largest ever found in the United States. It is about ten feet long, six feet high, and four feet thick, and weighs over fifteen tons.

In the Field Museum of Natural History, Chicago, and in the Natural History Museums of New York and Washington, are a number of meteoric irons known as *Canyon Diablo meteorites*. Lying some miles east of Canyon Diablo, in northern Arizona, is "Meteor Crater," about which masses of meteoric iron are scattered in concentric distribution to a distance of nearly five miles. Thousands of specimens of the iron have been collected in the district, varying in weight from a fraction of an ounce up to over half a ton, some of which became popularly famous because they contained minute fragments of diamond.

The "crater" is a bowl-shaped hole some four thousand feet in diameter, and about six hundred feet in depth, whose walls rise about one hundred and fifty feet above the outlying plain, and is supposed by Barringer, Merrill, and other observers, to have been formed by the impact of a mass of meteoric iron of enormous and hitherto unprecedented size, but which remains as yet undiscovered. It has been conjectured that this monster meteorite had a probable diameter of five hundred feet, and was one of a flock of meteorites that formed the nucleus of a large comet, which possibly struck the earth at this point, according to geological indications, not more than five thousand years ago.

The Yerkes 40-inch Refractor

(The largest *refracting* telescope in the world. Its big lens weighs 1,000 pounds, and its mammoth tube, which is 62 feet long, weighs about 12,000 pounds. The parts to be moved weigh approximately 22 tons.

The great *100-inch reflector* of the Mount Wilson reflecting telescope—the largest *reflecting* instrument in the world—weighs nearly 9,000 pounds, and the moving parts of the telescope weigh about 100 tons.

The new *72-inch reflector* at the Dominion Astrophysical Observatory, near Victoria, B. C., weighs nearly 4,500 pounds, and the moving parts about 35 tons.)

INDEX

E

F

G

M

Q

R